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FORECASTS OF THE EFFECTS OF AIR AND WATER POLLUTION CONTROLS ON SOLID WASTE GENERATION

Ralph Stone and Company, Incorporated

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The effects of air and water pollution controls on solid waste generation were evaluated. The solid wastes from pollution control were identified for individual industrial sectors by their original air or water pollutant constituents, and the treatment process applied. The wastes were categorized by type and by location (rural or urban). Total solid wastes from pollution control activities were estimated for 1971 and projected for 1975, 1980, and 1985. Particulates and sulfur oxides were identified as the major air pollutants capable of generating solid wastes when treated; suspended solids and biological oxygen demand were identified as the principle sources for the impact of water pollution control on solid wastes. Important sectors generating solid wastes included power plants (SIC 491), paper and pulp (SIC 26), chemicals (SIC 28), cement and clay (SIC 324-326), steel furnaces (SIC 331), nonferrous smelting and refining (SIC 333, 334), sewerage systems (SIC 4952), and hazardous wastes from uranium mining (SIC 10). Mine tailing ponds were estimated to be a greater source than all the above sources but are not an urban landfill disposal problem since they are mostly located in rural areas. An 83 page Executive Summary of this report has been published and is available separately (EPA-670/2-74-095a).

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

Recognizing the interplay among the components of our physical environment, this study presents quantitative estimates of the effects of air and water pollution controls on the generation of wastes destined for land disposal.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

The effects of air and water pollution controls on solid waste generation were evaluated. The solid wastes from pollution control were identified for individual industrial sectors by their original air or water pollutant constituents, and the treatment process applied. The wastes were categorized by type and by location (rural or urban). Total solid wastes from pollution control activities were estimated for 1971 and projected for 1975, 1980, and 1985. Particulates and sulfur oxides were identified as the major air pollutants capable of generating solid wastes when treated; suspended solids and biological oxygen demand were identified as the principle sources for the impact of water pollution control on solid wastes. Important sectors generating solid wastes included power plants (SIC 491), paper and pulp (SIC 26), chemicals (SIC 28), cement and clay (SIC 324-326), steel furnaces (SIC 331), nonferrous smelting and refining (SIC 333,334), sewerage systems (SIC 4952), and hazardous wastes from uranium mining (SIC 10). Mine tailing ponds were estimated to be a greater source than all the above sources but are not an urban landfill disposal problem since they are mostly located in rural areas.

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SECTION I

CONCLUSIONS

Sources of Pollution that Generate Solid Waste Residues.

1. The major air pollutants that generate solid waste residues when controlled are particulates and sulfur oxides. Control of carbon monoxide generates no solid waste residues, and control of nitrogen oxides generates relatively insignificant amounts. Hydrocarbons, when in particulate form, generate solid residues if controlled by filter-type control devices as opposed to combustion afterburners. Few solid residues are created by the control of gaseous hydrocarbons. Miscellaneous other air pollution control activities, principally fluoride and hydrogen sulfide control, create solid residues, but their contribution to the total solid residues resulting from air pollution control is negligible due to the relatively small total National discharges when compared to the total particulate and sulfur oxide discharges.

2. The major water pollutants capable of generating solid waste residues when controlled are suspended solids, dissolved solids, and biological oxygen demand (typically measured as BOD_5). Certain commonly-used wet process air pollution treatments, such as limestone scrubbing, generate suspended solids which add to the total water pollutant load. Acids in water generate solid wastes when inert salts are formed by their neutralization or precipitation.

3. A relatively small number of industrial sources generate the majority of air and water pollutants whose control creates solid waste residues. These main industrial sources are: Feedlots (SIC 02), suspended solids and BOD_5; Mining (10-12,14), suspended solids and acidity; Meat and Dairy Products (201,202), suspended solids and BOD_5; Canned and Preserved Fruits and Vegetables (203), suspended solids and BOD_5; Grain Mills (204), particulates; Paper and Allied Products (26), suspended solids, BOD_5, and particulates; Chemicals (28), suspended solids and SO_x; Petroleum Products (13,29), suspended solids, BOD_5, particulates, and SO_x; Cement and Clay Products (324-326), particulates; Blast Furnaces and Basic Steel Production (331), particulates; Iron Foundries (332), particulates; Nonferrous Smelting and Refining (333,334), suspended solids, particulates, and SO_x; Steam Electric Power Plants (491), particulates and SO_x; Sewerage Systems (4952), suspended solids and BOD_5; and Solid Waste Incineration (4953), particulates.

4. Of the major industrial sources, power plants, steel production, cement and clay production, and nonferrous metallurgy are the largest contributors to air pollution; they generated 63 percent of all uncontrolled particulates and 77 percent of all uncontrolled sulfur oxides in 1971. The largest point source contributors to water pollution (excluding mining) are sewerage systems, paper products, steel products, and feedlots; they generated 69 percent of all uncontrolled suspended solids and 75 percent of all uncontrolled BOD_5 in 1971. Mining operations generate suspended solids in quantities large enough to make the other industrial contributions insignificant;

however, these solids are generated and normally disposed in the immediate vicinity of the mine, posing no significant urban treatment and disposal problems.

5. Excluding mining pollution control, in 1971, control of particulates accounted for 62 percent of total solid residues from pollution controls, with sulfur oxide and other air pollutant controls accounting together for only one percent of the total residues. Control of all water pollutants accounted for the remaining 37 percent of total solid residues. By 1985, these respective contributions to total solid waste residues are forecast to change to particulate control--36 percent, sulfur oxide control--44 percent, other air pollutant controls--0.2 percent, and water pollution control, the remaining 20 percent.

6. Urban storm drain runoff, conventionally considered as one non-point source for other substances causing water pollution, is actually a significant pollution source caused by man's activities. Although contributions of storm drainage to water pollution are unquantifiable due to lack of sufficient investigation, future increased treatment of the runoff in sewerage systems could result in considerable quantities of solid wastes. Agricultural drainage is another significant non-point pollution source.

Pollutant Abatement Measures and Their Impacts on Residues.

1. Principal pollutant discharge abatement alternatives are pollution treatment processes and process modifications designed to eliminate uncontrolled industrial pollution discharges. The end products of pollution treatment processes are typically solid or liquid wastes ("solid waste residues") which must be disposed, most often to land, provided they are not reused or recycled. The effect of reuse and recycling, relative to the disposition of these residues is to reduce the amounts that must be disposed. The effect of industrial discharge-reducing process modifications is to lower the total pollutant load that ordinarily must undergo treatment, thus indirectly reducing the solid waste residues resulting from pollution treatments.

2. Common air pollution treatment process alternatives are wet versus dry and physical versus chemical. Dry processes generally produce solid waste residues directly, while wet processes (e.g., scrubbers) create residues suspended in water which must be removed by water treatments. Physical (filtration) processes (e.g., baghouses, scrubbers), generally are employed for particulate control and create solid residues approximately equal to the weight of the pollutant removed. Chemical treatment processes (e.g., limestone scrubbers), often used for sulfur oxide control, usually add reacting chemicals to the original pollutants and create solid residues greater in weight than the original pollutant. Limestone scrubber residues are over twice the weight of the SO_x removed from the stack gases.

3. Common water pollution treatment processes may be classified as primary, secondary and tertiary. Primary (physical) treatments (e.g., screening, sedimentation, flotation) generally remove suspended and flotable solids, creating solid waste residues equal in weight to the orignal pollutant. Secondary treatments, which are

either biological or chemical, can result in either less (via biological decomposition) or more (via chemical addition) solid residue weight than that of the original pollutant, depending on the specific treatment(s) involved. Efficient biological treatment residues from the treatment of organic wastes may range from as low as 25 percent of the BOD_5 removed (lagoons) to 50 percent of the BOD_5 (activated sludge). Where the pollutants do not decompose easily, these ratios may be considerably higher.

Tertiary treatments of organic waste streams, due to extensive solids removal by the noted primary and secondary treatments, usually contribute only small amounts of organic solid residues, but may generate extensive salt residues where demineralization is employed for inorganic waste streams.

4. In 1971, solid waste residues from pollution control were due largely to wet air treatments not involving addition of reactants (accounting for 49 percent of all solid residues) and primary wastewater treatments (accounting for 20 percent). By 1985, 40 percent of all residues are expected to be produced from wet air treatments involving addition of chemical reactants (e.g., limestone scrubbing), 32 percent are forecast to be produced from wet air treatments not involving chemical addition, and only 12 percent are forecast to be produced from primary wastewater treatment processes.

Impacts of Federal Pollution Control Legislation on Solid Waste Management.

1. The major Federal legislative measures that affect the type and quantities of solid wastes generated from air and water pollution control are the Federal Water Pollution Control Amendments of 1972; the Marine Protection, Research, and Sanctuaries Act of 1972; and the Clean Air Act of 1970. In general, the effect of this Federal legislation is to increase the quantities of solid waste residues from air and water pollution control by banning or reducing pollutants discharged to the air and water.

2. The Clean Air Act of 1970 will have significant impacts on particulate and sulfur oxide emissions. Particulate emissions, which are currently (1974) partially controlled, will be further controlled in the future. Sulfur oxide emissions, currently (1974) largely uncontrolled on a National basis, will be greatly reduced in the future. Air pollutant control levels will increase to at least 90-95 percent of untreated emissions by 1977 as a result of the Clean Air Act, although no Nationwide deadline is specified in the Act. No concrete requirements have yet been legislated for the likely increased treatment requirements beyond 1977.

3. Water pollution control legislation requires secondary treatment and, to a limited extent, tertiary treatment to be employed for most wastestreams by 1977. By 1983, discharges to water are required to be further reduced, in part by additional secondary and tertiary treatment beyond the 1977 control levels.

4. Air and water pollution control legislation will increase the quantities of solid waste residues to the extent that they require or otherwise result in increased application of pollution treatment processes; this study assumes that increased application of controls will probably be industry's short term (i.e., pre-1985) answer to strict emissions requirements. If long-term economic considerations dictate increased process modifications and/or increased recycling and reuse by industry as a result of strict emissions requirements, then the increased solid waste residues resulting from Federal legislation will in turn be reduced.

Effects of Pollution Control Measures on Solid Waste Management.

1. The largest weight of solid residues from pollution control activities is contributed by the mining industry. However, the solid residues produced are not a problem for urban solid waste management, as they are generally non-hazardous and disposed in the immediate vicinity of the mining operations, usually in rural areas.

2. The solid waste residues from pollution control in feedlots, meat and dairy products, canned and preserved fruits and vegetables, grain mills, paper products, and sewerage systems are easily decomposible. These residues may also contain some toxic constituents.

3. The solid waste residues from pollution control in cement and clay products, blast furnaces and basic steel production, iron foundries, and fossil fuel plants, although not in general highly toxic, are largely inert and do not decompose.

4. Radioactive solid residues from pollution control activities in nuclear power plants and fuel reprocessing plants are generally further concentrated and handled as solid residues; the wastes from nuclear power plants pollution control generally have both shorter half-lives and lower levels of radioactivity than solid or liquid wastes from nuclear reprocessing plants.

5. Radioactive solid residues from uranium and related nuclear source mine tailings are the largest source of radioactive wastes from air and water pollution control. These wastes, although having a low level of radioactivity, contain many long-lived isotopes and the resulting tailing piles remain hazards to the environment for many years.

6. Residues from air and water pollution control form a significant portion of total National solid waste production from the following sectors: residential, commercial, institutional, industrial, and mineral. Wastes from pollution control in point source agricultural activities form an insignificant proportion of the total National agricultural solid waste production.

SECTION II

RECOMMENDATIONS

On the basis of the work performed and the conclusions reached in this study, two sets of recommendations are listed below. The first set deals with specific areas in which further research data acquisition, or new methodologies are needed to more fully assess the solid waste implications of pollution control. The second set of recommendations, although not strictly within the assigned forecast nature of this project, nevertheless stem immediately from the forecasts presented throughout this report. The second set interprets data obtained in this study to suggest alternative strategies and policies capable of reducing the solid waste impact of pollution control activities.

Further Research Needed.

1. Future effluent guidelines and other detailed studies of industrial pollution control should require a mass balance analysis similar to that done in parts of the effluent guidelines report for Feedlots.[263] The mass balance allows an analysis of the inter-media effects of specific pollution controls.

2. An in-depth National survey of the recycling potential for solid residues from air and water pollution controls should be made to fill the very large gap in the available literature.

3. Methods of stimulating the reuse of solid waste residues from fossil fuel power plant pollution controls should be developed to reduce the solid waste impact of this important sector.

4. A detailed National assessment of solid residues from air and water pollution control in the main industries responsible for the generation of hazardous wastes, both radioactive and non-radioactive, should be made.

5. A National survey of the sulfur content of the Nation's fossil fuel reserves should be made to more accurately estimate solid wastes produced from sulfur oxide control in fossil fuel power plants.

6. Environmental impact reports should be required to include evaluations of the solid waste impact of proposed developments to aid in more comprehensive environmental planning trade-off analyses.

7. Improved methods are needed for segregation of solid wastes by types and characteristics of waste handled in order to allow for optimum disposal and/or reuse. Combustible solid wastes could be reclaimed for power generation, while toxic wastes should be segregated and neutralized before entering the main solid waste streams.

8. An analysis of the pollutants contained in urban and agricultural runoffs, other non-point sources, and the potential solid waste residues from their control should be made. These

latter pollutants, conventionally considered as natural or non-point source pollution are, in reality, a by-product of society's activities. These runoffs should be so identified and their generation quantified to aid in establishing valid water pollution control strategies.

Alternatives for Reducing Impact on Solid Waste Management.

1. Reuse of residues from pollution control should be encouraged, since it would reduce the adverse impacts of control activities on solid waste management. For example, pulping of reclaimed paper produces less pollutants than the production of pulp from raw materials, and in addition reuse reduces the wasted paper to be disposed.

2. In order to minimize the impact on solid wastes, consideration should be given to modifications in the organization of industrial production instead of simply adding controls to the existing organization of production. For example, the current (1974) requirement for use of available low sulfur fuels is effective in reducing the potential solid wastes from sulfur oxide control.

3. Where practicable, reuse, recycling of wastes, and process modifications should be emphasized in relation to pollution treatments generating solid wastes. Pollution controls will create solid residues both directly (from trapped emissions) and indirectly (from manufacture and operation of control equipment and the energy requirements for these activities).

SECTION III

INTRODUCTION

Objectives and Scope of Study.

The study objectives as set forth in the authorized work program were:

1. Review the available literature from published EPA reports, "The Intermedia Aspects of Air and Water Pollution Control,"[11] and supplemental data sources. Review available predictions concerning economic growth and the trends in industrial production methodology.

2. Identify the major air and water pollutants capable of creating solid wastes when controlled and the SIC code sources of these pollutants.

3. Identify the pollution abatement measures, their costs, and their impact upon solid waste generation.

4. Review Federal pollution control laws as they affect the degree and type of waste treatments that may be required through 1985.

5. Forecast the effects of pollution control measures on solid waste generation through 1985. Establish both the quantities and characteristics of these latter solid waste residues.

This last study objective was to predict the degree that control of air and water pollution will increase the quantities of solid wastes destined for land disposal. To accomplish the study objectives, it was necessary to first provide an inventory of all SIC code[268] industrial air and water pollution discharges before treatment, and then predict the waste treatment processes that will be applied, establish the resulting solid waste residues, and the probable disposal techniques for these solid residues. The extent to which these residues will be recovered for useful purposes was an important component in the analysis.

This study was not concerned with solid wastes normally resulting from industrial process steps per se, but rather with those solid wastes resulting from air and water pollution control activities. More specifically, this study was concerned with the increases in solid waste residues destined for land disposal as a result of air and water pollution control activities between the years 1971 and 1985. The distinction between all solid wastes generated by a particular industry sector and those generated as a result of air and water pollution control activities is important. For instance, most feedlot wastes are collected as solids and ultimately reclaimed as a soil conditioner; were animal manure alternatively flushed to a waterway, however, the manure would become a water pollutant requiring treatment. The land disposal of feedlot wastes was not considered as increased waste disposed to land resulting from water pollution controls, since these solid wastes result from typical feedlot process steps. As another example of the distinction between all solid wastes and increases in pollution-control related solid waste residues, consider the landfilling of solid wastes by municipalities. Such landfilling is a standard municipal solid waste disposal method; over time, however, regulatory air pollution legislation, such as bans on incineration may force increasing amounts of solid waste to be disposed to landfills. This study was undertaken to forecast the types and amounts of the latter types of solid waste, i.e., that resulted from legislated air and water pollution control regulations between 1971 and 1985.

The scope of this study was National, encompassing all solid wastes generated from air and water pollution control activities by all the private industrial and public sectors in the 50 States of the Union.

Method of Analysis.

The terms and abbreviations used in this report are defined in the Glossary (Section XXII). Commonly used terms have been utilized wherever possible.

Because of the individual requirements for specific pollution treatment processes and individual problems with residue reuse and disposal in the different SIC-coded industrial sectors, it was necessary to evaluate the solid waste residues for each industry separately. This was true for the industries generating large quantities of residues; lesser industries (in terms of residues) were discussed jointly in Section XVIII. For the purposes of the study analysis, a standard in-house analytical format was used. This format consisted of a set of eight tables which, when completed, fully described the solid residues resulting from pollution-control for each industry. The interdisciplinary nature of this study suggested the standardized format to aid in obtaining uniform data and common calculations and data evaluations. The eight basic tables (referred to in the remainder of this Section as Tables 1 through 8) characterized the process sources of air and water pollutants, untreated discharge factors, future growth in emissions, air and water treatments likely to be used, the degree of recycling of any solid residues, the total production through 1985 of solid waste residues, and a characterization of those residues.

Table 1 ("Sources before Treatment of Pollutants Capable of Producing Solid Waste") was used to characterize the uncontrolled discharges of any air and water pollutants capable of producing solid waste residues when treated (presented in terms of kg (dry) of pollutant per physical unit of production). Where possible the metric ton (kkg) was used as the physical unit of production, so that the pollutant discharge rate could be expressed as kg pollutant/kkg product. Where alternative production methods are possible within any particular industry, separate discharge factors were given for the different processes.

Table 2 ("Summary of Available Industrial Growth Forecasts") summarized available estimates of growth for the sector being studied. Where possible, growth in the alternative production methods cited in Table 1 was also forecast. Table 3 ("Comprehensive Forecast of Industrial Growth") synthesized the forecasts contained in Table 2 into comprehensive forecasts for the years 1971, 1975, 1980, and 1985 of growth in physical output and likely production processes. Table III-1 lists the main macro-economic indicators in the Predicasts forecasts. The comprehensive forecasts in Table 3 were, where possible, made consistent with the macro-economic assumptions in Table III-1. This was not always possible, as the need to forecast individual production processes and growth in particular products responsible for pollutant emissions required the use of data in industry trade journals and other sources which many times neglect to state macro-economic assumptions about the general growth of the economy. Table III-1 lists the main macro-economic indicators in the Predicasts forecasts. These forecasts are consistent with the individual forecasts in the Sections where possible.

Table 4 ("Discharge Inventory before Treatment of Pollutants Capable of Producing Solid Waste") resulted from the multiplication of Tables 1 and 3. Kilograms pollutant discharged per physical unit produced multiplied by physical units produced yielded kilograms of pollutant emission for 1971, 1975, 1980, and 1985. These discharges were then used as the inputs to the likely treatment processes in order to predict solid waste residues from air and water pollution control.

Table 5 ("Likely Pollution Treatment Processes Capable of Generating Solid Waste") listed the likely treatment processes to be applied to air and water pollutants now or in the future. The efficiencies and the resultant solid residues were given for each treatment method. Where the efficiencies or the resultant residues differed for different production steps or methods, the treatments were evaluated separately. Wherever possible, in the interests of brevity, production methods were grouped to show the combined treatment efficiency for a particular pollutant for all intra-sector sources. Whenever cost data were readily available and could be used to predict treatment methods most likely to be used, the costs per physical unit treated were cited in the table. It was found, however, that for most industries, the trade reports and government publications (e.g., The Economics of Clean Air) listed the probable treatments to be applied taking into consideration many factors other than treatment cost. Thus, the independent estimation of cost was given a lower priority in determining likely treatment methods shown in Table 5 than were efficiency and residue data.

The residues in Table 5 were estimated in kilograms of residues (dry) per kg of pollutant removed. For physical removal methods this ratio is invariably one. For chemical and biological treatment systems, however, the ratio may obviously differ from one.

Table 6 ("Reuse Potentials for Solid Residues Produced by Pollution Treatment Processes") characterized the residues produced in a general way and estimated the degree of recycling (% reuse) of these residues. This ratio is crucial to a final estimate of solid wastes to be sent to landfills. This percentage, unfortunately, was also the most difficult to establish based on recent published (1974) data. A simple telephone survey attempted to estimate the degree of reuse and provided considerable data. Approximately 50 plants in the key industrial polluting sectors were contacted.

TABLE III-1
MACROECONOMIC INDICATORS USED FOR ECONOMIC FORECASTING

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Population		10^6 persons			207	214	224.7	236.0	127	1973
Civilian employment		10^6 workers			79.1	87.7	95.8	102.5		
GNP		10^9 \$ (1970 prices)			1,001.2	1,215	1,473	1,750		
Disposable personal income		10^9 \$ (1970 prices)			717.3	843	1,025	1,220		
Net exports		10^9 \$ (1970 prices)			1.1	3	4	5		
Govt. expenditures		10^9 \$ (current)[a]			338.9	486.7	693	982.3		
FRB Industrial Production Index										
Industry production		Index (1967 = 100)			106.8	137	167	201	127	1973
Manufacturing					105.2	135	166	198		
Durable mfg.					99.4	131	160	191		
Nondurable mfg.					113.6	142	174	210		
Non mfg. production					118.9	146	179	217		

[a] Current refers to prices in the forecast years without using a deflator to account for inflation.

Table 7 (Total Impact of Pollution Treatment Processes on Solid Waste Residues") incorporated the relevant data in the previous six tables to arrive at a final solid waste residue estimate. First, the total residues from each treatment process were calculated by multiplying the discharge quantities (Table 4) by the percentage of discharge receiving a particular treatment process. This product was multiplied by the ratio of solid residues to the weight of pollutants removed by the particular treatment process. This calculation yielded the total solid residues resulting from an assumed 100 percent treatment efficiency. This produce was then multiplied by two percentages; first, a realistic treatment efficiency, and then the percent of net solid residues not reused or recycled. This yielded a final estimate of the solid waste residues resulting from air and water pollution control. The sequence of calculation was performed for each forecast year--1971, 1975, 1980, and 1985 separately. Occasionally, it was necessary to fill out Table 7 sequentially, that is, to show air pollutants treated by wet scrubbers creating water pollutants and then providing a separate water pollutant treatment discussion relating to this air pollution source.

In mathematical form, the process used to derive these final estimates of solid waste residues may be reduced to the following equations:

III-(1) $R_{ixy} = p\,(r \cdot E \cdot Z)$

where:

R_{ixy} = total residues from a particular treatment process i in industry x (units = kg) generating pollutant y

p = percent of a particular pollutant y treated by process i (no units)

r = solid residues that would be produced by process i assuming it were 100 percent efficient (units = kg)

E = the actual efficiency of process i in trapping pollutant y (no units)

Z = the percent of the residues provided from process i that are not forecast to be reused

The total solid residue estimate (Ri) provided by industry i was obtained by summing over residues produced by all treatment processes for all pollutants, as in equation 2:

III-(2) $R_x = \sum_i \sum_y R_{ixy}$

Once the total solid waste residues were estimated, Table 8 ("Composition of Solid Waste Residues from Pollution Treatment Processes") was employed to characterize these residues. All available pertinent information was coded, including a standard list of physical, chemical, and biological characteristics and a tabulation of special characteristics (e.g., radioactivity). This sometimes required separate tables to summarize the different types of solid waste residues.

Throughout the above analysis confidence levels were given to the data. These are also explained in detail in Appendix A. The levels are 4, 3, 2 and 1, corresponding, respectively, to a ± 10, 25, 50 and ≧ 100 percent possible variation in the data. These values may be translated as indicating a 90 percent probability that the true value for the data lies within either 10, 25, 50, or 100 percent of the value cited.

In addition to the tables, industry and treatment process schematics were developed in each Section in order to clarify the interrelationships of the data presented in the tables and to clarify the nature of the production methods and steps which result in the discharge of air and water pollutants. These schematics give a qualitative overview of the quantitative information presented in the tables.

Pollutants, Treatment Processes, and Solid Waste Management: An Overview.

Pollution Sources Considered in this Report. An attempt to include in the analysis all significant sources of air and water pollutant discharges capable of the generation of solid waste residues when controlled was made. Although the accuracy of the individual estimates varies, the sources covered in this report probably cover 95 percent of the air and water pollutant emissions in the U.S. which could impact on solid wastes from point sources.

Certain major polluting sectors were omitted from this report due to their lack of relevance to solid waste considerations. No detailed analysis was made of automobile or other transportation sources which generate large amounts of air pollutants because of lack of significant impact on solid wastes when controlled. The impact of storm drainage was not evaluated; storm drains concentrate water pollutants largely resulting from man's activities. However, because these (predominantly urban) sources are presently mostly uncontrolled, and because no National plan for controlling them has yet been developed, water pollutants in storm drainage were not considered in this study. It should be kept in mind, however, that the treatment of storm drain waters would also generate large amounts of solid residues and would, in addition, be extremely expensive. It will be necessary to extensively evaluate these water pollutants and their solid waste impacts in the future. Other non-point pollution sources such as agriculture, silvaculture, landfill drainage also require particular evaluation.

Hazardous Solid Residues from Air and Water Pollution Control. In addition to forecasting the mass and characteristics of the major pollutants capable of generating solid waste residues from air and water pollution control activities, a preliminary analysis was made of hazardous waste streams resulting from air and water pollution control. Because of the limited nature of the available information, the separate Section (Section XIX) is much more qualitative than other analyses in this report. Some preliminary estimates were made, but they are admittedly weak. The major sources of hazardous wastestreams considered were: pesticides, munition plants, radioactive wastes (mainly from nuclear power generation), chemicals manufacture, and metals mining, smelting and refining. Radioactive wastes are included as part of the Section on steam electric power plants.

Pollutant Treatments and Intermedia Transfers. On an inter-industry basis, it was concluded from preliminary analyses that particulates and sulfur oxides are the major air pollutants generating solid waste residues following treatment. Hydrogen sulfides and fluorides are also contributors to these solid waste residues, but are generated in relatively small amounts by only a few industries. Control of carbon monoxide and gaseous hydrocarbons will have minimal impact on solid waste residues through 1985, due largely to the fact that likely controls for these pollutants convert them to products released to the air. Table III-2 summarizes common air pollutants, their likely treatment methods, and the intermedial transfers created via treatment in a qualitative manner. Particulates are normally controlled by physical filtration, using either dry (e.g., precipitators, baghouses) or wet (e.g., wet scrubbing) methods. Sulfur oxides, if not reclaimed for sulfuric acid or elemental sulfur reuse, are normally controlled by chemical reaction with reactants such as limestone (either dry or wet methods are used) and dolomite. Reactions with limestone create calcium sulfates and sulfites weighing approximately twice as much as the sulfur oxides removed. All wet treatment methodologies result in transfer of suspended and dissolved solids to water, where final residues are then created during water treatments.

Determination of solid residues from water pollution control is made more complex by the diverse physiochemical nature of solids in water and the use of a wide variety of physical, chemical, and biological treatment methods both within and between industries. On an inter-industry basis, BOD$_5$ and suspended solids are reasonable indicators of solid residues created from biological treatments, although knowledge of organic content of solids in water and the ratio of total dissolved to suspended solids (generally unavailable) would enable more accurate prediction. Table III-3 qualitatively summarizes water pollutants, their likely treatment processes, and intermedial transfers created via treatment. The weight of residues from a variety of preliminary treatments is normally equal to the weight of suspended solids removed, usually 60 to 80 percent of the suspended solids in the treatment influent. Activated sludge treatment is estimated to create sludge solids equal to half of the BOD load in the influent following preliminary treatments.[153] Trickling filters normally create approximately 90 percent of the residues created by an activated sludge plant for a similar influent stream. Lagoons create even less residues, as they do not normally require pretreatment and thus decompose many of the organic suspended solids removed by pretreatment in activated sludge or trickling filter plants. For lagoons, in general, a total residue of 0.25 times the influent BOD$_5$ is a good estimate. Thus, total weight of residues may be estimated from influent suspended solids and BOD$_5$; other special pollutants in the influent are useful for determining the specific nature of the solid residues created.

Overview of Pollution Treatment Processes. This section will provide a brief overview of the most common air and water pollution control devices listed in Tables III-2 and III-3. Most of the descriptions were modified from the 1973 Environmental Wastes Control Manual[435], which provides more detailed information on pollution control devices. Air pollution control methods can generally be categorized as filtration, scrubbing, cycloning, electrostatic precipitation, incineration, oxidation, and adsorption. The most common type of filtering devices employed for air pollution control are baghouse filters ; these can produce high collection efficiency of particulates. Baghouses operate by using fabric

TABLE III-2
INTERMEDIA TRANSFERS IN AIR TREATMENTS

	AIR POLLUTANTS								INTERMEDIA TRANSFERS		
Treatment	Oxides of Nitrogen	Oxides of Sulfur	Carbon Monoxide	Hydrocarbons - Particulate	Hydrocarbons - Gaseous	Particulates	Radioactivity	Thermal	Air	Water	Land
Water Scrubbing		●		●		●		●		SS, TDS, H_2SO_3, H_2SO_4 Pathogens, Heat	
Electrostatic Precipitator				●		●	●			Residues[a]	Residues
Cyclones-Dry				●		●				Residues	Residues
Settling Chambers				●		●					Residues
Baghouse Filters				●		●	●				Residues
Condensers-Boiler Coolers								●		Heat	
Afterburners	●		●		●	●		●	CO_2 H_2O Heat		
Adsorbers				●	●	●				Recycled	
Venturi Scrubbers (Wet Cyclone)		●		●		●				H_2SO_3, H_2SO_4 Pathogens	

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[a] "Residues" indicates the same or a combined form of the pollutant is physically removed.

TABLE III-3
INTERMEDIA TRANSFERS IN WASTEWATER TREATMENT

	WATER POLLUTANTS												INTERMEDIA TRANSFERS		
Treatments	Radioactivity	Organics-Soluble	Inorganic - Soluble	Organics-Insoluble	Inorganic-Insoluble	Sulfur Compounds	Phosphorus Compounds	Nitrogen Compounds	Heavy Metals	Pathogens	Thermal	Acidity/Alkalinity	Air	Water	Land
Screening				●	●										Residues[a]
Flotation	●			●											Residues
Coagulation and Sedimentation	●			●	●		●		●	●					Residues
Chemical Addition	●	●	●	●	●	●	●	●	●			●		Compounds formed	Compounds formed
Trickling Filter		●	●	●	●					●					Residue
Activated Sludge		●	●	●	●	●	●	●		●				Residue	Residue
Lagoons and Stabilization Ponds		●		●	●	●		●						Residue	Residue
Ion Exchange			●			●	●	●	●			●			Residue
Activated Carbon		●		●		●		●	●				Volatile Compounds	BOD, SS NO_3 heavy metals	Residue
Reverse Osmosis			●			●	●	●	●					Residues	Residue
Chlorination										●					
Spray Irrigation		●		●		●	●	●		●					
Ammonia Stripping								●					NH_3	$CaCO_3$	$CaCO_3$
Cooling Towers											●		Heat	Residues	Residues
Retention[b]	●													Low-level Radioactivity	Radioactive Drums
Electrodialysis			●			●	●	●	●					Residues	Residues

a. Residues mean the same or a combined chemical form of the pollutant is physically removed.

b. Retention by storage as used in nuclear power plants.

filters with openings usually around 100 μ , to separate particles from their air medium. The filters are contained by structures known as baghouses. To clean baghouse filters, the bags are mechanically shaken to remove trapped particles; reverse air cleaning is sometimes used.

Scrubbers are useful for removing particulates, acids, fumes, and gases; their use for controlling sulfur oxides emissions is widespread. Scrubbers operate by causing surface contact between a liquid medium, usually water, with air pollutants. The water often has additives such as detergents or caustics (lime or limestone) to increase removal efficiencies. Scrubbers may operate by the water spraying against baffles or in packed towers. In venturi scrubbers, the air and water media are injected into a venturi tube.

Cyclones are mainly used for particulate control, operating on the principle of centrifugal force. Particulates are removed by contact with the walls of the collector and subsequently settle in the cone of the separator. Electrostatic precipitators are also used for particulate control. This control device ionizes gases with a high voltage corona discharge. The charged gas ions then charge particulates which migrate to a collecting electrode where they are neutralized by an opposite charge. Electrodes are cleaned either by rapping or water washing.

Incineration is generally used to burn combustible fumes at high temperatures. Combustibles may also be controlled by catalytic oxidation. Gases are preheated and passed over a catalyst to achieve oxidation at lower temperatures than possible with simple incineration. The catalyst is usually a nickel alloy.

Adsorbers are capable of selectively removing gaseous air pollutants from the air medium. Activated carbon adsorption, the most common adsorption method, is used to absorb organic gases and odors. Less common adsorption methods used silica gel medium to remove both organic and inorganic gases and alumina and bauxite media to achieve dehydration.

Water pollution control devices may generally be classified as primary, secondary, and advanced treatment methods. Primary treatment involves physical removal of suspended pollutants through the use of screening and settling processes. Screens employed may either be coarse or fine, and are generally used to remove the less dense suspended solids. More dense suspended pollutants, such as cinders, and metal fillings, are removed through grit collection, in which the velocity of the effluent is slowed to allow differential settlement of the heavier solids. The lighter solids are often removed by clarification in settling tanks; flotation, flocculation and sludge-thickening methods are often included in the clarification step.

The term secondary treatment encompasses several treatment methods; the EPA has defined secondary treatment as those processes producing the following effluent quality: BOD_5 and SS at a maximum monthly average of 30 mg/l, fecal coliform at a maximum monthly average of 200/100 ml, and pH equivalent to 6 to 9, on a scale of 1-10. The main units of secondary treatment are activated sludge, oxidation ponds, and trickling filters. In conventional activated sludge processes, the effluent, following settling, is aerated for 6-8 hours. Aeration may also be accomplished in oxidation ponds. Aeration functions to biologically stablize the liquid phase of the effluent. Biological stabilization by trickling filters involves passing effluent over rock or slag to which microorganisms are attached.

Advanced wastewater treatment functions to remove additional solids, organics, and pathogens still present in the effluent following secondary treatment. A wide variety of treatment processes are available for this further treatment. These include electrodialysis for demineralization,reverse osmosis to remove suspended and dissolved solids, lime or alum coagulation to remove phosphates, dual medium filtration to remove suspended solids, activated carbon beds for organics removal, and coagulant addition (principally aluminum sulfate, ferric chloride, ferric sulfate, and ferrous sulfate) to remove a variety of pollutants.

Effects of Federal Legislation Requiring Pollution Control on Solid Waste Management.

In order to estimate the future degree of pollution treatment in the various industries, it was necessary to first review the relevant Federal legislation. Recent relevant Federal environmental protection legislation includes the Federal Water Pollution Control Amendments of 1972; the Marine Protection, Research, and Sanctuaries Act of 1972; and the Clean Air Act of 1970. The following is a summary of major provisions of the three laws whose implementation will have National impact on the environmental distribution of solid wastes.

Federal Water Pollution Control Act Amendments of 1972. The goals of this law are to achieve, by July 1983 wherever possible, water clean enough for both human body contact and the continued existence of fish, shellfish, and wildlife; these goals further specify the elimination of the discharge of municipal and industrial point source pollutants into the Nation's waterways by July 1985. Pollutants to be controlled under the Act include, but are not limited to: dredged soil, solid waste, incinerator residue, sewage, sewage sludge, garbage, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural wastes discharged to water.

Industrial Pollution Treatment. The EPA is in the process of establishing effluent limitations and performance standards for categories of stationary industrial pollution sources which include the following sectors: industrial pulp and paper mills; paperboard, builder's paper, and board mills; meat product and rendering processing; dairy product processing; grain mills; canned/preserved fruits and vegetables processing; canned/preserved seafood processing; sugar processing; textile mills; cement manufacturing; fertilizer manufacturing; petroleum refining; iron/steel manufacturing; phosphate manufacturing; steam electric power plants; ferroalloy manufacturing; leather tanning and finishing; glass/asbestos manufacturing; rubber processing; and timber products processing.

The EPA, in accordance with the FWPCA goals, has issued development documents for effluent limitation guidelines listing the "best practicable" and "best available" technologies for the treatment of waste prior to discharge to receiving waters; these reports identify pollution control methods for the complete elimination of industrial discharges to waters. Existing stationary industrial sources discharging pollutants to the Nation's waters must use the "best practicable" control technology by July 1977, and the "best available" by July 1983. New industrial sources of pollution must use the "best available demonstrated control technology" by May 1974. Where practicable, new industrial facilities may be prohibited from discharging any pollutants to the Nation's waters. For all industrial wastes discharged to a municipal treatment plant, pretreatment will be required by July 1974 for new industrial facilities, and by July 1976 for existing industrial facilities.

Municipal Pollution Treatment. The Federal Water Pollution Control Amendments of 1972 require that treatment plants approved before July 1974 must provide a minimum of "secondary treatment" to qualify for Federal construction grants; after that date, "best practicable" treatment must be used. By July 1977, all sewage treatment plants in operation must provide a minimum of "secondary treatment" and must also comply with any additional effluent limitation established by either the EPA or the State. By July 1983, all publicly-owned waste treatment plants in operation must use "best practicable" treatment methods. The EPA will encourage management providing for recycling of pollutants, confined or contained disposal where not recycled, wastewater reclamation, nonhazardous final sludge disposal, integrated sewage, and industrial or other municipal waste treatment and recycling facilities.

Water Quality Standards. The discharge to navigable waters of any radioactive, chemical or biological warfare agent, and of any high-level radioactive waste, is prohibited by these amendments. In addition, the EPA is to identify substances which in any quantity present an imminent and substantial danger to the public health or welfare, whose discharge is also to be prohibited. Federal standards of performance for marine sanitation devices will be established by the EPA and Coast Guard.

The EPA will publish criteria relating to the following: chemical, physical, and biological integrity of water; the protection and propagation of fish, shellfish, and wildlife; recreational use; measurement and classification of water quality; maximum daily load requirements; best practicable control technology to achieve effluent reduction; pretreatment guidelines; and pollution discharge source categories. States must adopt intrastate water quality standards subject to EPA approval, and the EPA will establish such standards in the event a State fails to do so. If the "best practicable" or "best available" controls are inadequate to meet water quality standards, the State is required to impose stricter controls. To this end, the State must establish daily maximum total load standards. The Corps of Engineers may issue permits for the discharge of dredges or fill material; these permits are subject to EPA prohibition if unacceptable adverse effects on municipal water supplies, fish, wildlife, or recreational areas would result.

The NPDES Permit System. Under the 1972 law, it is illegal to discharge any pollutant to National waterways without an NPDES (National Pollutant Discharge Elimination System) permit. Point sources requiring a permit for water pollutant discharges include municipal wastewater treatment facilities, all point source industrial sectors, and any other service, wholesale, retail, and commercial establishments. The NPDES permit system is to assure that effluent limitations and performance standards are met, that necessary anti-pollution technology is applied, and that all other measures of the amendments are met.

The NPDES permit system can be seen as the implementation mechanism for the 1972 law. The permits specify allowable types and concentrations of pollutants that may be discharged by each point source; they are fixed for a period of time not exceeding five years. If immediate compliance with these standards is not forthcoming, the permits set target dates for progressive steps towards compliance. If the conditions of the permit are violated, or if a point source is found to be illegally discharging without a permit, the discharger faces the prospect of penalties, including fines and sometimes imprisonment. State permit programs are subject to the 1972 Federal Water Pollution Control Amendments; State permit programs must be approved by the EPA, and the EPA is responsible for issuing permits if State permit programs are not deemed acceptable.

Marine Protection, Research, and Sanctuaries Act of 1972. This Act bans the transport or dumping of any radiological, chemical, or biological agent, or high-level radioactive waste, within the 12-mile territorial limit. The EPA is authorized to issue permits for the transport and dumping of waste materials which would not unreasonably endanger human health and welfare or the marine environment, and to designate sites where transport and dumping are prohibited. The Corps of Engineers is authorized to issue permits for the transport and dumping of dredged or fill materials. The limit on ocean dumping will necessitate alternative methods for disposal of these wastes.

Clean Air Act of 1970. This Act is intended to control two types of air pollutants, those which endanger public health or welfare, i.e., pollutants having an adverse effect on the environment or public health; and those considered "hazardous," i.e., pollutants which may cause or contribute to increased mortality or irreversible and incapacitating illness.

Ambient Air Quality Standards. The EPA is authorized to establish primary (public health) and secondary (welfare) ambient air standards for each pollutant from stationary or mobile sources judged to endanger public health or welfare. No ambient air standard, however, is applicable to hazardous air pollutants. Each State is required to develop plans subject to EPA approval which include emission limitations; timetables; land-use transportation controls; and appropriate devices, systems, and monitoring requirements. The EPA is authorized to act if States fail to provide for the implementation of Federal ambient standards or the enforcement of National emission standards and requirements. No industry-wide deadlines exist for implementation of EPA required emission standards. However, most sources will be required to improve controls over present levels by 1976.[177] The Economics of Clean Air[89] lists forecast control levels for emissions in major polluting industries for 1977; no data are available for controls to be established beyond 1977.

Stationary Sources. The EPA will maintain a list of categories of stationary sources which may contribute significantly to air pollution, establish National standards of performance for new sources within each category, and issue information on related pollution control techniques. State plans may include standards and requirements for pollutant emissions from existing stationary sources for which no Federal standards have been issued, and may implement the Federal standards for existing or new stationary sources.

The EPA will publish a list of hazardous air pollutants, issue information on control techniques and establish emission standards. No new source or modification of an existing facility may violate hazardous pollutant standards. The EPA may, however, grant waivers of up to two years for existing sources.

Mobile Sources. It was required by the Clean Air Act, by 1975, that carbon monoxide and hydrocarbon emissions from light-duty automotive vehicles and engines must be reduced a minimum of 90 percent based on model-year 1970 averages; by 1976, oxides of nitrogen emissions must be reduced a minimum of 90 percent based on model-year 1971 averages. The EPA may control the sale or commercial use of automotive fuel or additives which either endanger the public health or impair the emission control system or device. Subsequent rulings by the EPA in 1973[59, 106], however, have resulted in the delay of full-scale implementation of these requirements.

Effects of Federal Legislation on the Disposition of Solid Waste Residues. The effects of the above-mentioned three laws, and particularly the FWPCA Amendments of 1972 and the Clean Air Act of 1972, will generally be to increase the amounts of solid waste residues that are disposed to land. The goal of these laws is the reduction and eventual elimination of pollutant discharges to air and water media. This abatement of discharges can generally be accomplished via two alternatives; treatment and capture of pollutants vs. process modifications designed to eliminate pollutant production. To the extent that abatement is accomplished by treatment methods as opposed to process modifications, the amounts of solid waste residues destined for land disposal will increase in the future; at least in the short-term, the general answer of municipalities and industries to Federal air and water pollution control legislation seems to be a preference towards installing pollution control devices, rather than switching to more non-polluting technologies and practices.

Current trends in pollution abatement measures dictated that this study assume increased application of pollutant treatment methods will comprise the bulk of industry's short-term (pre-1985) response to the goals and requirements of Federal air and water pollution control legislation. If long-term economic considerations or technological breakthroughs result in increased use of more non-polluting processes or increased amounts of reuse and recycling of wastes, the amount of solid waste residues destined for land will correspondingly be reduced. The possibility exists that future Federal legislation or economic incentives will require or stimulate the incorporation of more non-polluting processes or increased reuse and recycling of wastes, thus mitigating the solid waste impacts of existing legislation.

SECTION IV

ANIMAL FEEDLOTS
SIC 02

Introduction.

Animal feedlots comprise that portion of livestock production which is performed with "a high concentration of animals held in a small area for periods of time in conjunction with one of the following purposes:"[261] meat, milk, eggs, and breeding stock production, and stabling of horses. Feedlot solid wastes, in addition to animal wastes, also include the residues from transportation of animals. Land used for feedlots will neither sustain vegetation nor be available for crop production.[261]

Feedlots can generate large amounts of water pollutants. Control of these pollutants generally creates by-products which, if not disposed of, are useful as organic fertilizers, soil conditioners and other uses; thus, the impact of water pollution control on feedlot solid wastes is to encourage their reclamation or alternative disposal into landfills to handle the large pollutant quantities involved. Some research work has also been done on reclaiming cattle dung as a cattle feed supplement. This reuse concept is not yet widely practiced, however. Although the solid waste impact of alternative treatment and disposal methods is fairly well known, no National engineering evaluations have yet established the degree to which alternate disposal techniques are used; thus, the National estimate of total solid waste generation from water pollution control in feedlots is necessarily rough. No discussion of air pollutants is presented in this Section, since feedlots generate essentially minor solid wastes from air pollution control.

Untreated Discharge Factors.

Air Pollutants. No air pollutants of major consequence are generated on feedlots. Odor is a problem on feedlots, but its control generates no solid waste. The following discussions will focus exclusively on the solid waste impacts of water pollutants.

Water Pollutants. Table IV-1 summarizes the amounts of the major water pollutants generated from different types of feedlots. A more complete breakdown of water pollutant discharges can be found in the recent EPA effluent guidelines report concerning feedlots.[261]

Two major wastewater discharge categories are given in Table IV-1: milk room and animal housing wastes; and runoff. The first category includes all wastes generated directly in the feedlot, including milk room wastes for dairies and bedding material mixed with manure. These wastes are listed as water pollutants since they often enter waterways through water-cleansing systems. In terms of pollutant discharges/head-day, large amounts of dry solids are generated from all beef cattle housing, dairy cattle manure and bedding, and dairy cattle milking center housing.

TABLE IV-1
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Beef Cattle:	All	head-day	Raw waste	22.0 (wet)	261
	Open lot		Dry solids	2.61	
			BOD_5	0.31	
			Inerts as ash	0.808	
			N	0.082	
	Slotted floor-shallow pit		Dry solids	3.3	
			BOD_5	0.45	
			Inerts as ash	0.77	
			N	0.12	
	Slotted floor-deep pit		Dry solids	3.0	
			BOD_5	0.3	
			Inerts as ash	0.95	
			N	0.4	
	Solid floor		Dry solids	3.8	
			BOD_5	0.4	
			Inerts as ash	2.0	
			N	0.08	
	Runoff		Dry solids	0.459[a]	
Dairy Cattle: Manure and bedding	Stall barn	head-day	Dry solids	4.2	261
			BOD_5	0.46	
			Inerts as ash	0.36	
			N	0.12	
	Free stall barn		Dry solids	8.2	
			BOD_5	0.90	
			Inerts as ash	0.70	
			N	0.22	

SOURCES BEFORE TREATMENT OF WATER. POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Dairy Cattle: Manure and bedding (Cont.)	Free stall, barn, liquid, flush, & slotted floor	head-day	Dry solids	5.16	261
			BOD_5	0.89	
			Inerts as ash	n.d.[b]	
			N	0.23	
	Runoff		Dry solids	0.459[c]	
	Cow yard		Dry solids	4.23	
			BOD_5	0.499	
			Inerts as ash	1.31	
			N	0.133	
Milking center	Stall barn	head-day	Dry solids	0.06	
			BOD_5	0.005	
			Inerts as ash	n.d.	
			N	0.00077	
	Free stall barn		Dry solids	0.08	
			BOD_5	0.059	
			Inerts as ash	n.d.	
			N	0.0068	
	Cow yard		Dry solids	0.4	
			BOD_5	0.17	
			Inerts as ash	n.d.	
			N	0.068	
Swine:	Solid concrete floor	head-day	Dry solids	0.2	261
			BOD_5	0.09	
			Inerts as ash	0.05	
			N	0.02	
	Slotted floor - pit		Dry solids	0.2	
			BOD_5	0.09	
			Inerts as ash	0.05	
			N	0.02	

TABLE IV-1 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Swine: (Cont.)	Runoff	head-day	Dry solids	0.186[d]	261
	Dirt lot manure		Dry solids	0.15	
			BOD_5	0.064	
			Ash	0.04	
			N	0.011	
Sheep:	Housed - solid manure	head-day	Dry solids	1.93	261
			BOD_5	0.16	
			Ash	0.36	
			N	0.0631	
	Housed - liquid		Dry solids	2.44	
			BOD_5	0.091	
			Ash	0.21	
			N	0.011	
	Partial confinement - house manure		Dry solids	0.967	
	Partial confinement - corral manure			0.504	
	Dirt lot manure			1.00	
	Corral runoff			0.091[e]	
	Dirt lot runoff			0.18	
Lambs:	Housed - solid manure	head-day	Dry solids	1.12	261
			BOD_5	0.0922	
			Inerts as ash	0.21	
			N	0.037	
	Housed - liquid manure		Dry solids	0.645	
	Partial confinement-manure			0.563	
	Partial confinement-corral manure			0.292	
	Dirt lot - manure			0.581	
	Corral - runoff			0.052	
	Dirt lot - runoff			0.105	
Chickens:		kg of bird/day	Dry solids	0.0174	261
			BOD_5	0.0094	
			Inerts as ash	n.d.	
			N	0.0082	

TABLE IV-1 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Turkeys: Breeders	Housed	head-day	Dry solids	0.170	261
			BOD_5	0.039	
			Inerts as ash	0.040	
			N	0.0082	
Growing	Housed	head-day	Dry solids	0.102	
			BOD_5	0.023	
			Inerts as ash	0.025	
			N	0.0050	
		head-day @ 4.3 kg/bird	Dry solids	0.064	
	Runoff		Dry solids	0.0044[f]	
Ducks:	Wet lots	head-day	Dry solids	0.044	261
			BOD_5	n.d.	
			Inerts as ash	n.d.	
			N	n.d.	
			SS	0.0248	
Horses:	Manure & bedding	head-day	Dry solids	17.3	261
			BOD_5	0.4	
			Inerts as ash	4.3	
			N	0.261	

TABLE IV-1 (Cont.)

SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE

SIC 02

[a] The discharge in Reference 273 for beef cattle was established by sampling a watershed directly below a feedlot. The dairy figure was determined more accurately by sampling directly downstream of a feedlot. The higher dairy figure of 0.086 kg pollutant (dry)/animal-day was multiplied by 5.34, the ratio of dry solids to BOD_5 noted in Reference 261 for runoff from a dirt, moderately sloped, beef feedlot.

[b] n.d. = no data available.

[c] This quantity is the runoff figure for dairy cattle of 0.086 kg/animal-day of BOD_5 from Reference 273 multiplied by 5.34, the ratio of dry solids to BOD_5 in runoff figures for a cow yard established in Reference 261.

[d] This quantity is the runoff figure for swine (direct discharge) from Reference 273 multiplied by 2.33, the ratio of dry solids to BOD_5 in runoff figures for a dirt swine feedlot noted in Reference 261.

[e] This quantity is the manure figure for partial confinement on dirt lots multiplied by the ratio of runoff to the open lot manure coefficient for beef cattle above (0.18).

[f] This estimate assumed the runoff figure for poultry (0.0002 kg BOD_5/bird-day) from Reference 273 multiplied by 4.4, the ratio of dry solids to BOD_5 in turkey manure from Reference 261 multiplied by 5, the ratio of the body weight of a turkey to the average body weight of a chicken.

The interpretation of storm drainage runoff wastes is more difficult. The amount of pollutants present in storm runoff is a function of the slope of the lot, the type of floor used, and especially of rainfall intensity. In the effluent guidelines report for this industry, the runoff figures are cited in terms of kilograms per animal per day per centimeter of runoff.[261] It would be difficult to calculate total pollution from these figures since there is no readily available computation of runoff by major geographical areas. Other, slightly older reports[273] have made preliminary estimates of generated pollutants in runoff per animal head per day. These estimates were used in Table IV-1. The BOD_5 estimate cited in Reference 273 was converted to total solids by using the ratio of total solids to BOD_5 in the pollutant per animal head per day per centimeter runoff cited in the EPA effluent guideline. Runoff data for ducks, horses, dogs and cats were generally not available, and these were omitted since they account for a relatively insignificant proportion of the total pollutants in storm drain runoff. However, since they may be an important aspect of urban drainage, they should be further investigated. The confidence level for the wastewater pollutants generated, shown in Table IV-1, is about 2, indicating a 50 percent possible variation in the data.

Industry Description and Schematic.

Feedlot production when contrasted to range or farmland animal husbandry entails intensive solid waste concentration. Several alternative feedlot layout and waste management methods are possible. These alternatives are listed in Table IV-1 under each type of animal commonly produced in feedlots. Alternative production methods generally involve different procedures for animal housing and waste collection. It should be noted that there are other animal production methodologies, but they are not described in detail since they have little impact on the pollution generated by feedlots. Figure IV-1 illustrates the basic steps in feedlot production and the alternative production methods which will have different impacts upon solid waste generation. Open lots without collectors have the problem of drainage runoff control, while wastewater collection systems must handle the large quantities of manure, animal bedding, and for dairies, milk room wastes, in an efficient manner. Slotted floors and poultry cages have the advantage of requiring little or no animal bedding material. The wastewaters from wet manure removal systems (such as flushing) can be practically treated by lagooning, irrigating agricultural fields in slurry form, or by other common methods to remove the pollutants before discharge to receiving water bodies.

Economic Forecasts.

Table IV-2 summarizes available forecast data on animal feedlot production of eggs, meat, and milk in the United States. Most of the available data are in terms of animal populations for various feedlot types. It was necessary for the economic forecasting to estimate the average number of days spent by animals in feedlots in order to calculate total head-days. (A head-day is one day spent in a feedlot by one animal.) Most of the available data on time spent in feedlots were listed in the industry effluent guidelines report.[261] Table IV-3 converts the data in Table IV-2 on a head-day basis and makes forecasts for production through 1985. These comprehensive forecasts were necessary for

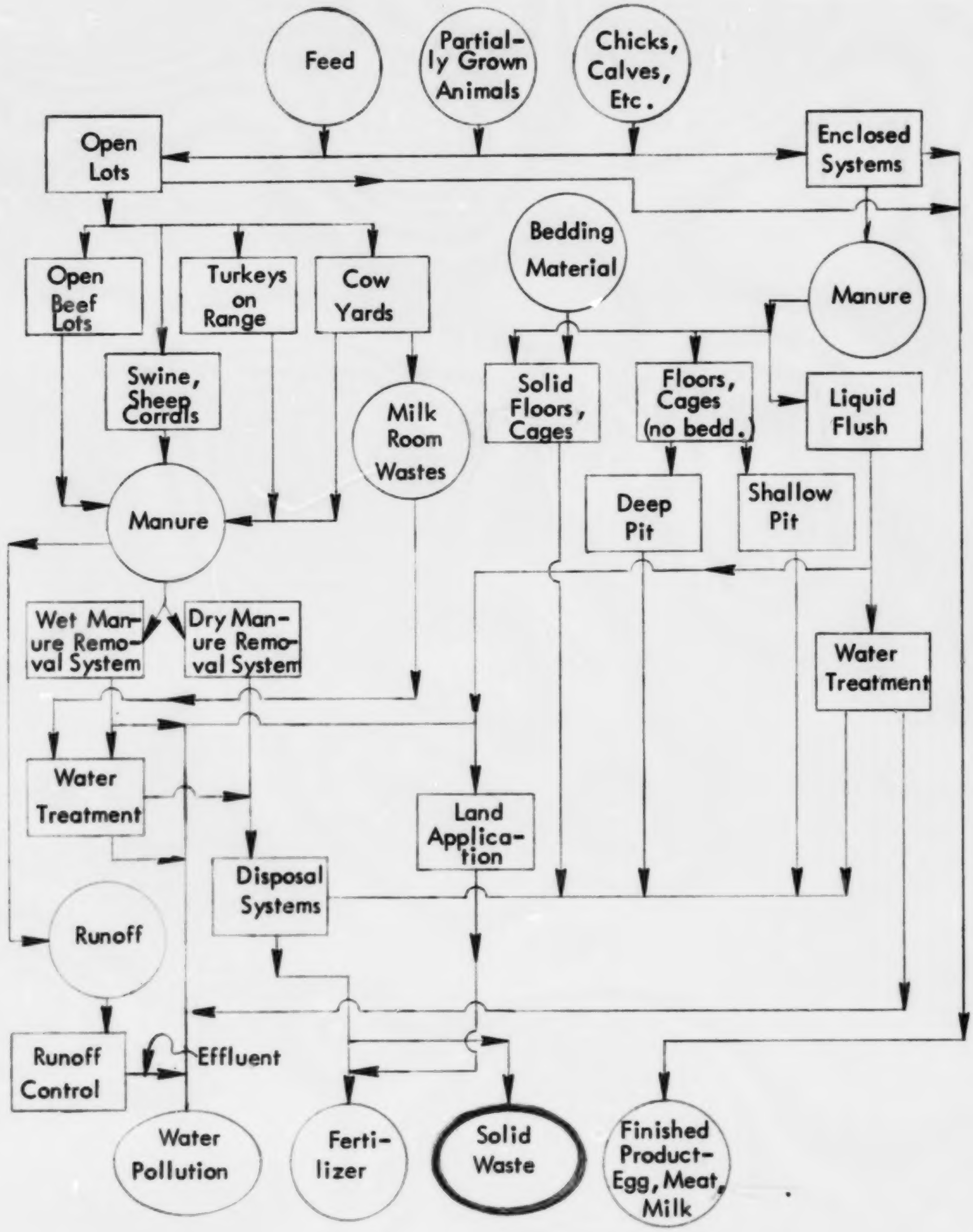
Feed
Partially Grown Animals
Chicks, Calves, Etc.
Open Lots
Enclosed Systems
Open Beef Lots
Turkeys on Range
Cow Yards
Bedding Material
Manure
Swine, Sheep Corrals
Milk Room Wastes
Solid Floors, Cages
Floors, Cages (no bedd.)
Liquid Flush
Manure
Deep Pit
Shallow Pit
Wet Manure Removal System
Dry Manure Removal System
Water Treatment
Water Treatment
Land Application
Disposal Systems
Runoff
Runoff Control
Effluent
Water Pollution
Fertilizer
Solid Waste
Finished Product-Egg, Meat, Milk

FIGURE IV-1
INDUSTRY SCHEMATIC:
FEEDLOTS

TABLE IV-2
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 02

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Dairy Cattle:									261	1973
Milk cows	Stall barn	10^6 cows	1972	6.8						
	Free stall barn-mech. scrape			1.6						
	Free stall barn-liq. storage			0.06						
	Barn-slotted floor			0.06						
	Free stall barn-liq. flush			0.06						
	Cow yards			2.92						
	All cows in dairies			11.5						
Replacement heifers, breed stock	Pasture	10^6 cows		4.5						
Weight/cow		kg		590-635						
Holstein		% of all cows		85-95						

TABLE IV-2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 02

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Beef Production:	Total slaughter	10^6 head			35.9				270	1973
		kg/head			466					
		10^6 kg/slaughter			16,700					
		days in feedlot/animal	1972	130-180					261	1973
	Population on feedlots	10^6 head	1972	14.0					261	1973
	Open lot			13.4						
	Slotted floor-shallow pit			0.06						
	Slotted floor-deep pit			0.19						
	Solid floor			0.35						
Calf Production:	Slaughter	10^6 head			3.8				270	1973
		kg/head			115.0					
		10^6 kg			440.0					
Hogs:									270	1973
All	Slaughter	10^6 head			95.5					
		kg/head			108.0					
		10^6 kg			10,350					
	Time on feedlot/hog	weeks		23-25					261	1973

TABLE IV-2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 02

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Breeders and market hogs	Solid concrete floor	10^6 hogs	1972	15.4					261	1973
	Slotted floor			9.2						
	Dirt or pasture			37.0						
Sheep and Lambs:										
All	Slaughter	10^6 head kg/head 10^6 kg	1972	10.97 46.7 514.0					270	1973
Sheep on feed	Housed	10^6 head	1972	0.52					261	1973
	Partial confinement			1.40						
	Dirt lot			0.35						
Lambs on feed	Housed	10^6 head	1972	0.09					201	1973
	Partial confinement			0.75						
	Dirt lot			1.10						
	Time on lot	days		95.0						
Poultry:									271	1972
Layers		10^6 eggs			71,644					

TABLE IV-2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 02

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Poultry:									271	1972
Layers (Cont.)	Layers on farms	10^6 birds			321.8					
	Eggs/hen/day	Eggs			0.61					
Chickens raised	Without broilers	10^6 birds			318				271	1972
Chickens sold	Without broilers	10^6 birds			258				271	1972
		10^6 kg			534					
		kg/bird			2.14					
	Growing time	days	1972	182						
Broilers	Produced on farms	10^6 birds			2,947				271	1972
		10^6 kg			4,886					
		kg/bird			1.66					
	Time in house	weeks	1972	8					261	1973
Turkeys	Slaughtered	10^6 kg	1972		1,027				272	1973
		kg/bird			8.5					
		10^6 birds			120.4					
	January 1 population	10^6 birds	1972	90.2					261	1973
	Housed			19.7						
	Open lot			70.5						
	Time on feed	weeks/bird		22						
Poults	Hatched	10^6 birds			115.4				272	1973

TABLE IV-2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 02

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Ducks	Slaughter	10^6 kg.			22.4				272	1973
		10^6 ducks			13					
		kg/duck			1.7					
	Time on lot	weeks/duck	1972	7.0					261	1973
	Total on feed	10^6 ducks		1.86						
	Dry lot			0.38						
	Wet lot			1.48						
Horses:	Population	10^6 horses		7.5					261	1973
	Popultation at race tracks			0.275						

TABLE IV-3
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

Item	Process or Activity	Physical Units (Metric)	1971 Quantity	1971 Ref. No.	1975 Quantity	1975 Ref. No.	1980 Quantity	1980 Ref. No.	1985 Quantity	1985 Ref. No.
Beef cattle	All	10^6 head-days	5,564	a	6,098	b	6,790	b	7,859	b
	Open lot		5,325	c	5,836	c	6,498	c	7,521	c
	Slotted floor shallow pit		24		26		29		35	
	Slotted floor deep pit		76		83		93		107	
	Solid floor		139		153		170		196	
Milk cows	All types	10^6 cow-days	4,198	d	4,198	d	4,198	d	4,198	d
	Stall barn		2,482	e	2,482	e	2,482	e	2,482	e
	Free stall dry mech. scrape		584		584		584		584	
	F.S.B.storage		22		22		22		22	
	F.S.B. slotted floor		22		22		22		22	
	F.S.B. liquid flush		22		22		22		22	
	Cow yards		1,066		1,066		1,066		1,066	

TABLE IV-3 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Hogs	All types	10^6 hog-days	16,044	f	16,358	g	16,987	g	17,616	g
	Solid concrete floor		4,011	h	4,580	h	5,266	h	6,166	h
	Slotted floor		2,396	i	2,781	i	3,228	i	3,523	i
	Dirt or pasture		9,637	j	8,997	j	8,493	j	7,927	j
Sheep on feedlots @ 120 days	All	10^6 sheep-days	272	k	272	k	272	k	272	k
	Housed		62	l	62	l	62	l	62	l
	Partial confinement		168		168		168		168	
	Dirt lot		42		42		42		42	

TABLE IV-3 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

Item	Process or Activity	Physical Units (Metric)	1971 Quantity	1971 Ref. No.	1975 Quantity	1975 Ref. No.	1980 Quantity	1980 Ref. No.	1985 Quantity	1985 Ref. No.
Lambs on feedlots @ 150 days	All	10^6 lamb-days	291	m	291	m	291	m	291	m
	Housed		14	n	20	n	26	n	29	n
	Partial confinement		112	o	116	o	122	o	131	o
	Dirt lot		165	p	155	p	143	p	131	p
Layers	All	10^6 hen-days	117,457	q	117,457	q	117,457	q	117,457	q
		10^6 kg hen-days	252,007	r	252,007	r	252,007	r	252,007	r
Replacement stock		10^6 pullet-days	57,876	s	57,876	s	57,876	s	57,876	s
		10^6kg pullet-days	52,505	t	52,505	t	52,505	t	52,505	t
Broilers		10^6 broiler-days	165,032	u	181,872	v	202,080	v	229,024	v
	0.9 kg broilers	10^6 kg broiler-days	149,717	w	164,894	w	183,327	w	207,770	w
Turkeys	All	106 turkey-days	18,540	x	20,400	y	24,100	y	25,960	y
	Housed		4,080	z	5,710	z	8,200	z	10,380	z
	Open lot		14,460	aa	14,690	aa	15,900	aa	15,580	aa

TABLE IV-3 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Ducks	All	10^6 duck-days	637	bb	637	bb	637	bb	637	bb
	Dry lot		130	cc	130	cc	130	cc	130	cc
	Wet lot		507	cc	507	cc	507	cc	507	cc
Horses	Race tracks	10^6 horse-days	100	dd	100	dd	100	dd	100	dd

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[a] 35.9 x 10^6 head slaughtered multiplied by average of 155 days per head spent on feedlots.

[b] Projected by growth rate in beef production from Section VI (Meat and Dairy Products).

[c] Based on breakdown of beef cattle population by feedlot type from Table IV-2, assumed constant.

[d] Cows in dairies not on pasture multiplied by 365 days per year.

[e] Based on breakdown of dairy types from Table IV-2, assumed constant.

[f] 95.5 x 10^6 hogs slaughtered in 1971 multiplied by average of 24 weeks/hog on feedlot.

[g] Projected by growth rate in pork production from Section VI (Meat and Dairy Products).

[h] Based on percentage of hog population on solid concrete floors, from Table IV-2 (25 percent) projected to increase to 35 percent by 1985.

[i] Based on percentage of hog population on slotted floors from Table IV-2 (15 percent) projected to increase to 20 percent by 1985.

TABLE IV-3 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

[i] Based on percentage of hog population on dirt or pasture from Table IV-2 (60 percent) projected to decrease to 45 percent by 1985.

[k] Based on sheep population of 2.27×10^6 head on January 1, 1972 multiplied by 120 days/head on feedlots. Constant through 1985 based on constant mutton production through 1985 from Section VI (Meat and Dairy Products).

[l] Based on breakdown of sheep population by feedlot type from Table IV-2.

[m] Based on 1.94×10^6 lambs on feedlots as of January 1, 1973 multiplied by 150 days per lamb on lots. The high figure was used to compensate for lambs raised at other times of the year. The exact proportion of total lamb production raised on lots was not available.

[n] Based on percentage of lambs on confined feedlots from Table IV-2 (5 percent) projected to increase to 10 percent by 1985.

[o] Based on percentage of lambs in partially confined feedlots from Table IV-2 (38 percent) projected to increase by 45 percent by 1985.

[p] Based on percentage of lambs in dirt feedlots from Table IV-2 (57 percent) projected to decline to 45 percent by 1985.

[q] Average of 321.8×10^6 layers on farms during 1971 multiplied by 365 days. Assumed constant based on data from Section on Meat and Dairy Products.

[r] Hen-days above multiplied by 2 kg/bird to get 1 kg equivalent hen-days for compatibility with Table IV-1.

[s] 318×10^6 replacement pullets raised in 1971 multiplied by 182 days per pullet; assumed constant through 1985 based on data in Section on Meat and Dairy Products.

[t] Above pullet-days converted to kg pullet-days @ 0.91 kg/pullet.

TABLE IV-3 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 02

[u] 2945 x 10^6 broilers produced times 8 weeks in house per broiler.

[v] Projected based on broiler meat production forecast from Section on Meat and Dairy Products.

[w] Above broiler days converted to kg-broiler-days at 0.91 kg/broiler.

[x] 120.4 x 10^6 turkeys slaughtered times 22 weeks per turkey on lot.

[y] Projected based on increases in turkey meat production forecast in Section on Meat and Dairy Products.

[z] Based on percentage of turkeys in enclosed housing from Table IV-2 (22 percent) projected to increase to 40 percent by 1985.

[aa] Based on percentage of turkeys in open lots from Table IV-2 (78 percent) projected to decrease to 60 percent by 1985.

[bb] 13 x 10^6 ducks slaughtered in 1971 times 7 weeks on feed per duck, assumed constant through 1985 based on data in Section on Meat and Dairy Products.

[cc] Based on data from percentage breakdown of ducks in wet and dry lots in 1971. Assumed constant through 1985 because of lack of further information.

[dd] 0.275 x 10^6 horses at racetracks times 365 days per year. Assumed constant through 1985 because of lack of further information.

subsequently predicting total pollutant load for this time period. Since only base year data were available for feedlots, the industrial growth estimates projected for meat, milk, and eggs were calculated and are noted in Section IV (Meat and Dairy Products) to forecast head-days. This method slightly overestimates growth, since improvements in the efficiency of feed to meat conversion for dairy products, and reductions in production time, are occurring.

Trends toward confined animal housing and paved feedlots are known to exist, although no specific data were readily available. Therefore, increasing percentages of total feedlot production in enclosed lots were forecast for several categories. Hogs raised on concrete or slotted floors should increase to 55 percent in 1985, from 40 percent in 1971. Lambs raised in partial confinement or enclosed housing are predicted to increase to 55 percent of total lamb-days spent in lots from 43 percent in 1971. Turkeys in housing are forecast to increase to 40 percent from 22 percent in 1971. No increase is forecast for dairy cows in enclosed lots, since most dairy cattle are already in enclosed stall barns or free stall barns. Enclosed housing or partial confinement for mature sheep should also remain constant, since 85 percent of the total sheep-days are already spent in such confinement. No changes are forecast in duck and horse raising methods, primarily because of specific data deficiencies. These sectors, however, are responsible for a relatively minor percentage of the total animal feedlot waste.

The above estimates in Table IV-3 are projections based on certain assumptions; the estimates are probably conservative since they assume continuation of current changes taking place in the feedlot industry. The confidence level for the forecasts made in Table IV-3 is 3-4, indicating a 10 to 25 percent possible variation in the predictions.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table IV-4 estimates the discharge inventories of all dry solids produced in feedlots. Estimates of both total manure produced and runoff are included and summed separately at the end of the table. The estimates were derived by multiplying the discharge factors for dry solids in Table IV-1 by the animal-day forecasts in Table IV-3. Total dry solids produced are forecast to increase to 56 billion kilograms in 1985 from 49 billion kilograms in 1971. Total dry solids in runoff are forecast to increase to 5.7 billion kilograms in 1985 from 4.9 billion in 1971; suspended solids in the runoff (calculated at approximately the 30 percent of dry solids in runoff from feedlots that appear as suspended solids) are forecast to increase to 1.7 billion kilograms from 1.5 billion in 1971. The discharge inventories in Table IV-4 may be given a confidence level of 2, indicating a ±50 percent possible variation in the data.

Likely Pollution Treatment Processes.

The wastes generated by feedlots are managed in three steps: removal, treatment, and ultimate disposal. Water treatment is shown schematically in Figure IV-2, and disposal alternatives are schematized in Figure IV-3. The manure produced by animals may be removed by mechanical pick-up methods (such as scraping), or may be flushed with water.

TABLE IV-4
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Dry solids	Beef cattle:	261				
	Open lot		13,898	15,232	16,960	19,630
	Shallow pit		79	86	96	116
	Deep pit		228	249	279	321
	Solid floor		528	581	646	745
	Open lot runoff	261 & 273	2,554	2,799	3,117	3,607
	Dairy cattle:	261[a]				
	Stall barn		10,424	10,424	10,424	10,424
	Free stall barn (FSB) mech. scrape		4,789	4,789	4,789	4,789
	FSB liquid storage		113	113	113	113
	FSB slotted floor		113	113	113	113
	FSB liquid flush		113	113	113	113
	Cowyards		4,509	4,509	4,509	4,509

TABLE IV-4 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Dry solids (Cont.)	Dairy cattle:					
	Milking center:	261				
	Stall barn		149	149	149	149
	FSB		52	52	52	52
	Cow yard		426	426	426	426
	Cow yard runoff		489	489	489	489
	Hogs:	261				
	Solid floor		802	916	1,053	1,233
	Slotted floor		479	556	646	705
	Dirt or pasture		1,446	1,350	1,274	1,189
	Dirt or pasture runoff		1,796	1,677	1,583	1,478
	Sheep:	261				
	Housed		120	120	120	120
	Partial confinement		247	247	247	247
	Dirt lot		42	42	42	42
	Partial runoff		15	15	15	15
	Dirt lot runoff		8	8	8	8

TABLE IV-4 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIÇ 02

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Dry solids (Cont.)	Lambs:	261				
	Housed		16	22	29	32
	Partial confinement		96	99	104	112
	Dirt lot		96	90	83	76
	Partial confine. runoff		6	6	6	7
	Dirt lot runoff		17	16	15	14
	Layers:	261	4,384	4,384	4,384	4,384
	Replacement: pullets:	261	914	914	914	914
	Broilers:	261	2,605	2,871	3,190	3,615
	Turkeys:	261				
	Housed		261	365	525	664
	Open lot		n.d.	n.d.	n.d.	n.d.
	Open lot runoff		64	65	70	69
	Ducks:	261				
	Wet lot		22	22	22	22

TABLE IV-4 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 02

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Dry solids (Cont.)	Horses:	261				
	At race tracks		1,730	1,730	1,730	1,730
Total dry solids (run off not included)			48,681	50,564	53,032	56,585
Total dry solids in runoff			4,949	5,075	5,302	5,687
Total SS in runoff (@ 30% of TS)			1,485	1,522	1,591	1,706
Total solids from[b] dirt lots			19,997	21,223	22,868	25,446
Total solids from[c] solid or slotted floors			28,690	29,341	30,164	31,139

TABLE IV-4 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE

[a] FSB = Free stall barn.

[b] Open lots for beef cattle, cow yards (not including milking center), dirt pasture hog feedlots, and dirt lots for sheep and lambs.

[c] Beef cattle except open lot, dairy cattle except cow yard, hogs except dirt or pasture, sheep except dirt lot, hogs except dirt lot, layers, replacement pullets, broilers, turkeys, ducks, horses, all excluding runoff. The item cow yard under milking center is milking center wastes for a barn with a cow yard and not cow yard wastes proper.

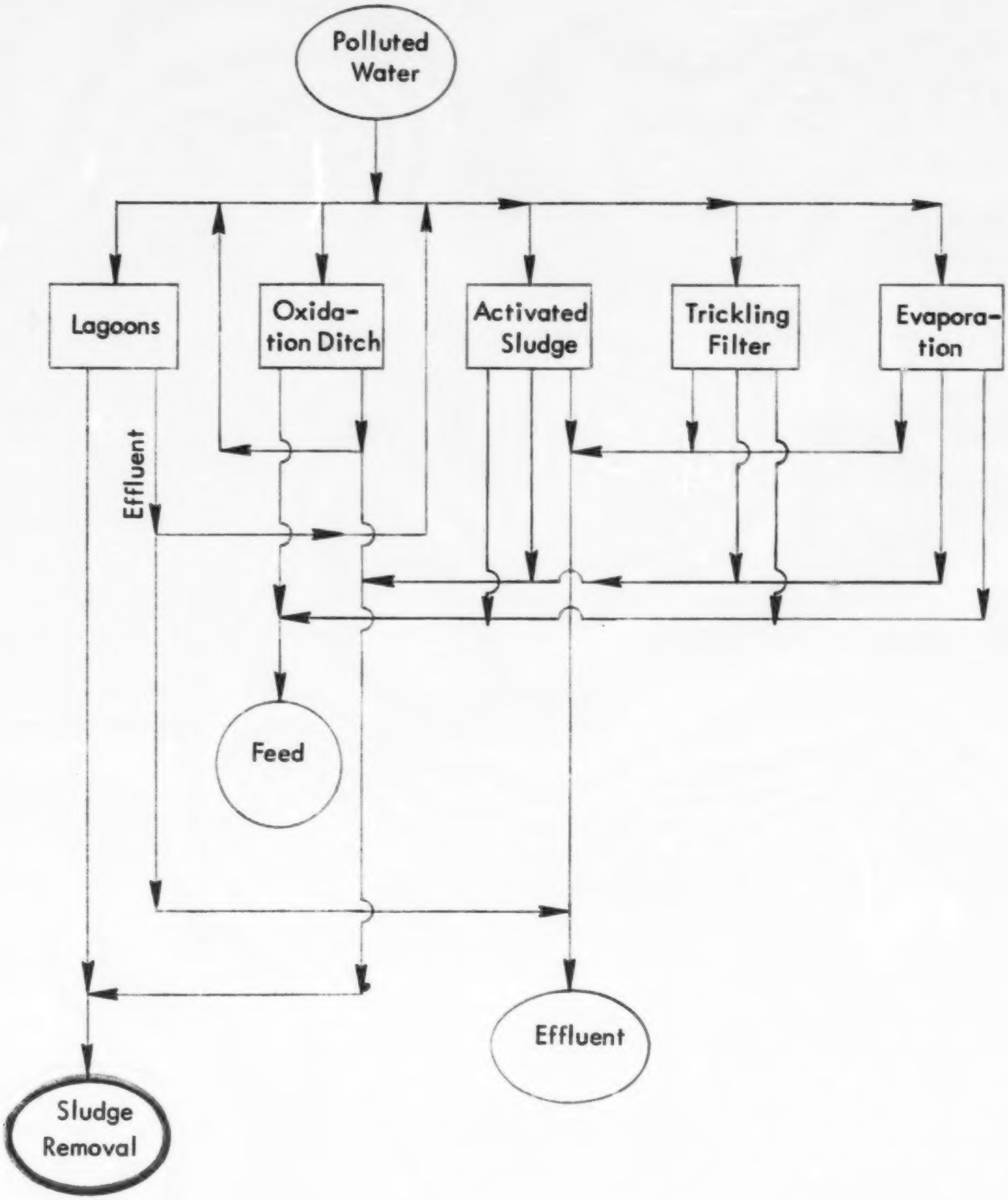
Polluted Water
Lagoons
Oxidation Ditch
Activated Sludge
Trickling Filter
Evaporation
Effluent
Feed
Effluent
Sludge Removal

FIGURE IV -2
WATER TREATMENT
PROCESS SCHEMATIC:
FEEDLOTS

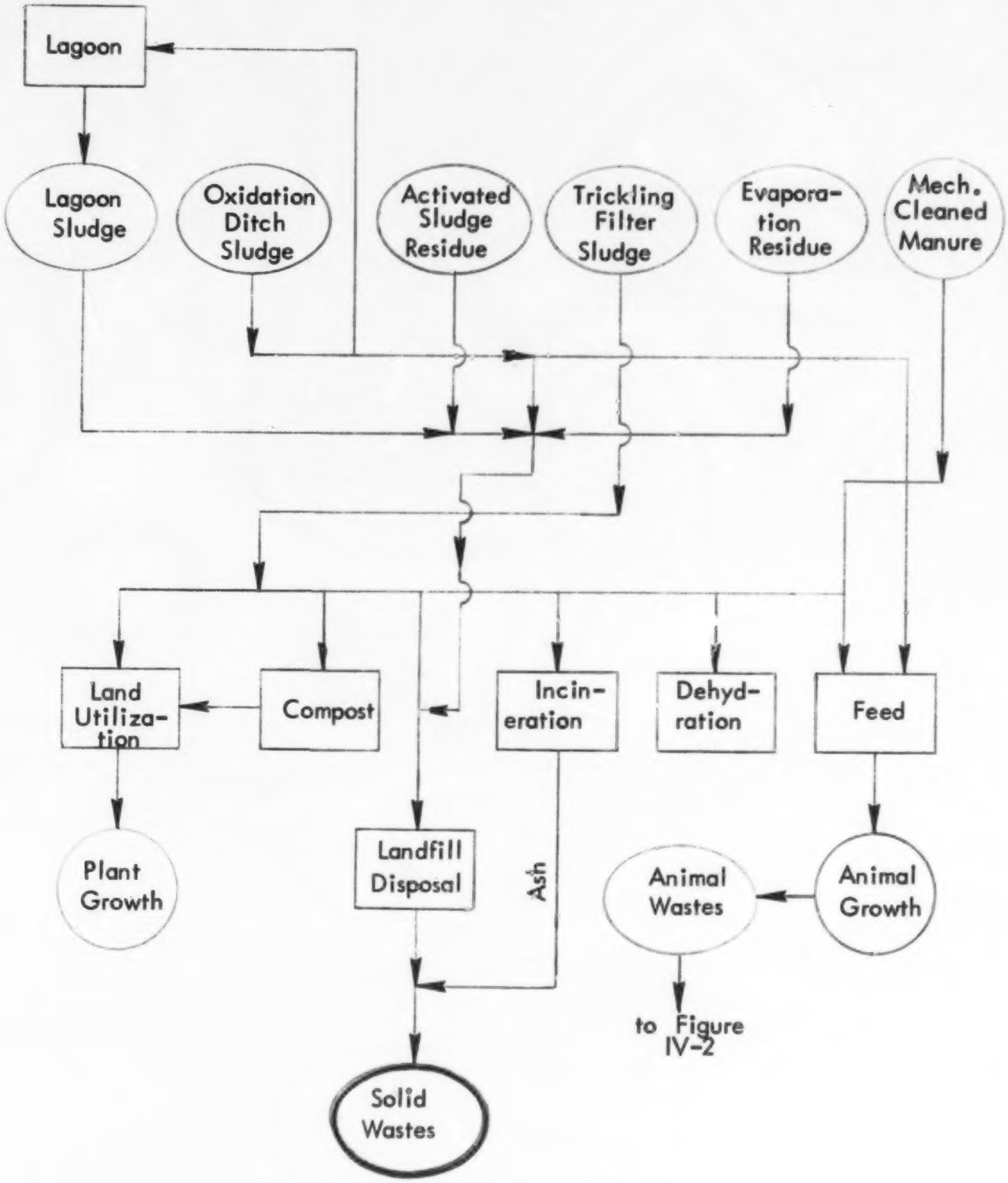
Lagoon
Lagoon Sludge
Oxidation Ditch Sludge
Activated Sludge Residue
Trickling Filter Sludge
Evaporation Residue
Mech. Cleaned Manure
Land Utilization
Compost
Incineration
Dehydration
Feed
Plant Growth
Landfill Disposal
Ash
Animal Wastes
Animal Growth
to Figure IV-2
Solid Wastes

FIGURE IV-3
WASTE DISPOSAL
PROCESS SCHEMATIC:
FEEDLOTS

Mechanical methods normally result in solid residues which are usually reclaimed, largely as soil conditioners and to a far lesser extent into feed products. Flushed wastes may require effluent treatment, as does the runoff contained within drainage control systems. The main, economical wastewater treatment processes are lagoons, oxidation ditches, activated sludge, and evaporation. However, many experimental processes are at the pilot stage. Table IV-5 lists all currently-accepted treatment and disposal methods and indicates their level of development as given in the feedlot effluent guidelines report.[261] Only the methods indicated as Best Practicable Control Technology Currently Available (BPCTCA) and Best Available Technology Economically Achievable (BATEA) were evaluated for the study forecasting purposes. Partial waste treatments in Table IV-5 are those treatments which leave some residue for solid waste disposal. Table IV-6 lists the alternative removal, collection, treatment, and disposal technologies and the solid residues created by each. The confidence level of the data in Table IV-6 is 3, indicating a possible 25 percent variation in the estimates.

Reuse Potential for Solid Waste Produced by Pollution Treatment Processes.

Table IV-7 lists the percentages of the residues disposed of by alternative methods, including reclamation. Composting and land spreading can result in complete residue control, while feed recycling results in approximately 80 percent reuse. Dehydration processes can convert about 43 percent of the waste residues into feed; the remaining 57 percent waste is usually disposed to land.[261] About twenty-five percent of oxidation ditch residues can be refed to animals and 75 percent can be disposed to land. These latter data are primarily based on mass balances developed in the EPA feedlot effluent guidelines report and appear to be reasonable. The estimates have a confidence level of 3, indicating a possible 25 percent variation in prediction.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables IV-8 through IV-11 estimate the total impact of solid waste residues from water pollution control in feedlots for the years 1971, 1975, 1980, and 1985. Total final solid waste residues from water treatments were 920 $\times 10^6$ kg in 1971. When solids removed in a dry state are included, total solid waste residues were 5,460 $\times 10^6$ kg. For 1975, solid waste residues were forecast to increase to 1,110 $\times 10^6$ kg from water treatment, and total 6,180 $\times 10^6$ kg including dry removal. For 1985, total solid waste residues are estimated to total 5,780 $\times 10^6$ kg. Thus, the trend in solid wastes generated from pollution control in feedlots appears relatively stable, with peak amounts being generated in 1980 and minimum amounts in 1985. The decline in waste residues between 1980 and 1985 is attributable mostly to a forecast switch in disposal methodology, with landfill disposal being replaced by recycling as feed to animals during this five-year period. These final forecast tables are derived somewhat differently than those in following sections because of the unique manner wastes are handled in feedlots.

The residues from manure removal by flushing and runoff control are fed into the water treatment processes; calculations from treatment were used to estimate the solid waste residues. Disposal techniques were next applied to the mechanically cleaned manure;

TABLE IV-5[261]
POLLUTANT TREATMENT AND DISPOSAL METHODS
SIC 02

	Application		Function			Status			Type of Process	
Technology	Manure	Runoff	Containment	Complete Treatment	Partial Treatment	BPCTCA	BATEA	Experimental	Biochemical	Physical Chemical
Land utilization	x	x		x		x			x	
Compost and sell	x			x		x			x	
Dehydration (sell or feed)	x			x		x (Sell)	x (Feed)			x
Conversion to industrial product	x			x				x		x
Aerobic SCP production	x			x				x	x	
Aerobic yeast production	x			x				x	x	
Anaerobic SCP production	x			x				x	x	
Feed recycling	x			x				x		x
Oxidation ditch (spread or feed)	x				x	x (Spread)	x (Feed)		x	
Activated sludge	x				x		x		x	
Wastelage	x				x		x		x	
Anaerobic fuel gas	x				x			x	x	
Fly larvae production	x				x			x	x	
Biochemical recycling	x				x			x	x	
Conversion to oil	x				x			x		x
Gasification	x				x			x		x
Pyrolysis	x				x			x		x
Incineration	x				x			x		x
Hydrolysis	x				x			x		x
Chemical extraction	x				x			x		x

TABLE IV-5[261] (Cont.)

POLLUTANT TREATMENT AND DISPOSAL METHODS

SIC 02

Technology	Application		Function			Status			Type of Process	
	Manure	Runoff	Containment	Complete Treatment	Partial Treatment	BPCTCA	BATEA	Experimental	Biochemical	Physical Chemical
Runoff control		x	x			x				
BLWRS		x		x				x	x	
Lagoons for treatment		x	x		x	x			x	
Evaporation		x	x		x	x				x
Trickling filters		x			x			x	x	
Spray runoff		x			x			x	x	
Rotating biological disks		x			x			x	x	
Water hyacinths*		x			x			x	x	
Algae*		x			x			x	x	

* Within lagoons

TABLE IV-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 02

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
All feedlots:		Dry solids	In-process technology:				261
Open lot			Scrape to 1 inch	80	0.9		
			Scrape just below manure	85	1.0		
Solid floor			Scraping	99	1.0		
			Flushing	100	n.a.[a]		
Slotted floor			Scraping	99	1.0		
			Flushing	100	n.a.		
Cages			Scraping	99	1.0		
			Flushing	100	n.a.		
All feedlots:			Runoff containment:	99	1.0		261
		Dry solids	Lagoons	60-80	0.10		
		Dry solids	Oxidation ditch & settling tank	90	0.34	Capital costs = $50/head	
		SS	Activated sludge (aeration)	90	0.5		
		SS	Trickling filter	70	0.45		
			Evaporation	90	0.8		

TABLE IV-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 02

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
All feedlots:		Solution/ water	Disposal systems:				261
			Land utilization	n.d.[b]	1.0		
			Composting		0.4		
			Incineration		0.2		
			Dehydration		1.0		
			Refeed (wastelage)		1.0		

---

a. n.a. - not applicable

b. n.d. - no data available

TABLE IV-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 02

Item and Pollutant	Process or Activity	Treatment/disp. Process	% Reuse	Ref. No.	Description/Disposal of Residue
All pollutants		Land utilization	100	261	Used as fertilizer
		Composting	100		Used as fertilizer
		Incineration	0		Ash-disposed to landfills
		Dehydration	43		Proteins usually used in feed
		Feed recycle process	80		Sand and fiber comprise 20 percent
		Oxidation ditch - refeed	25		25 percent in feed, waste residues sent to landfills
		Refeed directly (wastelage)	60		A portion directly refed to animals, rest is waste

TABLE IV-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC 02

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots	In-process technology:							
	Dirt lots	Scrape to 1 in.	50	(9,000)^a	80	(7,200)^a		
		Scrape below manure	50	(10,000)^a	85	(8,500)^a		
	Solid/slotted floors	Scrape	80	(22,930)^a	99	(22,700)^a		
	Total residues to disposal			(41,930)^a	n.a.	(38,400)^a	to solids disposal	
	Solid/slotted floors	Flush	20	(5,730)^b	100	(5,730)^b		
	Runoff control:		25	(1,240)^b	100	(1,240)^b		
	Total residues to water			(6,970)^b	n.a.	(6,970)^b	to water treatments	
	Water treatments:	Land spread	10	700	n.a.	700	0	0
		Lagoons	65	450	70	320	100	320
		Oxidation ditches	10	240	90	210	75	160
		Activated sludge	5	170	90	160	100	160
		Trickling filter	5	160	70	110	25	30
		Evaporation	5	280	90	250	100	250
		Total	100	2,000	88	1,750	58	920

TABLE IV-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 02

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots (Cont.)	Solids disposal	Land utilization	75	28,800	n.a.	28,800	0	0
		Composting	5	770	n.a.	770	0	0
		Incineration	2	150	100	150	100	150
		Dehydration	5	1,920	100	1,920	57	1,090
		Animal feed	3	1,150	100	1,150	40	460
		Direct to landfills	10	3,840	100	3,840	100	3,840
		Total		36,630	n.a.	36,630	15	5,540
Total Residues from Water Pollution Control				2,000	88	1,750	58	920

---

[a] The residue amounts from these processes are disposed of by several techniques differing greatly in final impact on solid residues. No net solid residues from pollution control have, therefore, been given here. The impact of the solid residues is incorporated in estimates of residues from solids disposal later in the table.

[b] The residues from these processes are transferred to water; no net solid residues are created before this transfer. The solid waste impact of these processes is incorporated in estimates of residues from water treatments, immediately below.

TABLE IV-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 02

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots	In-process technology:							
	Dirt lots	Scrape to 1 in.	50	(9,550)[a]	80	(7,640)[a]		
		Scrape below manure	50	(10,610)[a]	85	(9,020)[a]		
	Solid/slotted floors	Scrape	80	(23,470)[a]	99	(23, 230)[a]		
	Total residues to disposal			(43,590)[a]	91	(39,890)[a]	to solids disposal	
	Solid/slotted floors	Flush	20	(5,870)[b]	100	(5,870)[b]		
	Runoff control:		50	(2,540)[b]	100	(2,540)[b]		
	Total residues to water			(8,410)[b]	100	(8,410)[b]	to water treatments	
	Water treatments:	Landspread	10	850	n.a.		0	0
		Lagoons	65	550	70	380	100	380
		Oxidation ditches	10	290	90	260	75	200
		Activated sludge	5	210	90	190	100	190
		Trickling filter	5	190	70	130	25	30
		Evaporation	5	340	90	310	100	310
		Total	100	2,430	n.a.	1,270	87	1,110

TABLE IV-9 (Cont.)

TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 02

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots (Cont.)	Solids disposal	Land utilization	75	29,930	n.a.	29,930	0	0
		Composting	5	800	n.a.	800	0	0
		Incineration	-	-	100		100	
		Dehydration	10	3,990	100	3,990	57	2,270
		Animal feed	5	2,000	100	2,000	40	800
		Direct to landfills	5	2,000	100	2,000	100	2,000
		Total	100	38,720		38,720	13	5,070
Total Residues from Water Pollution Control				2,430	n.a.	1,270	87	1,110

---

[a] The residue amounts from these processes are disposed of by several techniques differing greatly in final impact on solid residues. No net solid residues from pollution control have, therefore, been given here. The impact of the solid residues is incorporated in estimates of residues from solids disposal later in the table.

[b] The residues from these processes are transferred to water; no net solid residues are created before this transfer. The solid waste impact of these processes is incorporated in estimates of residues from water treatments, immediately below.

TABLE IX-10
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 02

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots	In-process technology:							
	Dirt lots	Scrape to 1 in.	50	(10,290)[a]	80	(8,230)[a]		
		Scrape below manure	50	(11,430)[a]	85	(9,720)[a]		
	Solid/slotted floors	Scrape	85	(25,640)[a]	99	(25,380)[a]		
	Total residues to disposal			(47,360)[a]	n.a.	(43,330)[a]	to solids disposal	
	Solid/slotted floors	Flush	15	(4,540)[b]	100	(4,540)[b]		
	Runoff control:		90	(4,770)[b]	100	(4,770)[b]		
	Total residues to water			(9,310)[b]	n.a.	(9,310)[b]	to water treatments	
	Water treatments:	Land spread	10	930	n.a.	930	0	0
		Lagoons	60	560	70	390	100	390
		Oxidation ditches	10	320	90	280	75	210
		Activated sludge	5	230	90	210	100	210
		Trickling filter	10	420	70	290	25	70
		Evaporation	5	370	90	340	100	340
		Total	100	2,830	86	2,440	50	1,220

TABLE IV-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 02

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots (Cont.)	Solids disposal	Land utilization	75	32,560	n.a.	32,500	0	0
		Composting	5	870	n.a.	870	0	0
		Incineration	-				100	
		Dehydration	10	4,340	100	4,340	57	2,470
		Animal feed	6	2,600	100	2,600	42	1,090
		Direct to landfills	4	1,740	100	1,740	100	1,740
		Total	100	42,050	100	42,050	13	5,300
Total Residues from Water Pollution Control				2,830	86	2,440	50	1,220

---

[a] The residue amounts from these processes are disposed of by several techniques differing greatly in final impact on solid residues. No net solid residues from pollution control have, therefore, been given here. The impact of the solid residues is incorporated in estimates of residues from solids disposal later in the table.

[b] The residues from these processes are transferred to water; no net solid residues are created before this transfer. The solid waste impact of these processes is incorporated in estimates of residues from water treatments, immediately below.

TABLE IV-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 02

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids: All feedlots	In-process technology:							
	Dirt lots	Scrape to 1 in.	50	(11,450)[a]	80	(9,160)[a]		
		Scrape below manure	50	(12,720)[a]	85	(10,810)[a]		
	Solid slotted floors	Scrape	90	(28,030)[a]	99	(27,740)[a]		
	Total residues to disposal			(52,200)[a]	n.a.	(47,710)[a]	to solids disposal	
	Solid/slotted floors	Flush	10	(3,110)[b]	100	(3,110)[b]		
	Runoff control:		100	(5,690)[b]	100	(5,690)[b]		
	Total residues to water			(8,800)[b]	n.a.	(8,800)[b]	to water treatments	
	Water treatments:	Land spread	10	880	n.a.	880	0	0
		Lagoons	60	530	70	370	100	370
		Oxidation ditches	10	300	90	270	75	200
		Activated sludge	5	220	90	200	100	200
		Trickling filter	10	100	70	280	25	70
		Evaporation	5	350	90	320	100	320
		Total	100	2,680	86	2,320	50	1,160

TABLE IV-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 02

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total solids:	Solids disposal	Land utilization	75	35,780	n.a.	35,780	0	0
All feedlots		Composting	5	950	n.a.	950	0	0
(Cont.)		Incineration	-		100		100	
		Dehydration	10	4,770	100	4,770	57	2,720
		Animal feed	10	4,700	100	4,770	40	1,910
		Direct to landfills	-				100	
		Total	100	46,270		46,270	10	4,630
Total Residues from Water Pollution Control				2,680	86	2,320	50	1,160

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[a] The residue amounts from these processes are disposed of by several techniques differing greatly in final impact on solid residues. No net solid residues from pollution control have, therefore, been given here. The impact of the solid residues is incorporated in estimates of residues from solids disposal later in the table.

[b] The residues from these processes are transferred to water; no net solid residues are created before this transfer. The solid waste impact of these processes is incorporated in estimates of residues from water treatments, immediately below.

the percent solid waste was then calculated in order to forecast the total solid wastes disposed (after reuse) resulting from water pollution control. It should be realized that only about 15-16 percent of the residues for disposal are ever in water. The rest are from manure removed by mechanical methods. By 1985 the percentage in water is forecast to decline to 11 percent. In many cases, however, as in open feedlots, this is normal practice and has been for many years. For that reason, the solid waste residues which originally were actually removed from the water are listed separately at the bottom of each table. The data in Tables IV-8 through IV-11 can be given a confidence level of 1, indicating a possible 100 percent variation in the data.

Composition of Solid Waste Residues from Pollution Treatment Processes.

Table IV-12 presents a composite of raw feedlot wastes. The table was obtained by weighting the different manures (beef, dairy, swine, poultry, and sheep)[261] by the respective amounts of solids lost in runoff (Table IV-4). Biodegraded beef cattle manure was compared with fresh beef cattle manure (slotted floor, shallow pit). To obtain indices of change by biodegradation, these indices were extrapolated from the figures in Table IV-12 to obtain the figures for biodegraded waste in Table IV-13. The biodegraded waste has lower water content, BOD_5, and biodegradability, and higher ash content than the raw feedlot waste.

The types and quantities of toxic materials in feedlot wastes are mainly a function of the kind of feed used and the soil types on which the feed materials are grown. It can be assumed, as a fair approximation, that the toxic materials exist in manure in proportions similar to those in the "average" alfalfa, corn, or other feed meals. The concentration of such metals would increase concomitantly with the increase in ash content, upon biodegradation. The data used,[261] and the figures given regarding biodegradation, refer only to a step in the biodegradation process. Ultimately, in the "average" climate, all organic matter is biodegradable. However, incremental biodegradation may be extremely slow after one or two months of aerobic/anaerobic microbial activity.

Factors Affecting Quality of the Data.

The largest source of possible inaccuracy in the forecasts is the estimate made of the application of future waste treatment, removal, and disposal techniques. Although many reports discuss alternative processes and the efficiencies and residue production for each, no National survey has been made of typical waste disposal practices in feedlots.

The forecast breakdown of removal, treatment, and disposal processes used for final forecasting was estimated from the designations for the different processes with regard to the 1977 and 1983 effluent guidelines limitations (BPCTCA and BATEA).[261] Although these estimates are preliminary, it is clear that the trend is toward treatment and disposal techniques which generate minimum waste products. The effluent guidelines for feedlots states:[261]

TABLE IV-12

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 02

Item: Feedlots

Process or Activity: Raw feedlot wastes

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	8.9	261
Volume	l -wet	8.3	
H_2O content (of wet weight)	%	84.0	
Combustible	kg	0.7	
Non-combustible	kg	0.3	
Ash content	kg	0.3	
Liquid form	kg		
Solid form	kg		
Energy content	kcal		
Oxygen requirements	kg BOD_5	0.23	
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg	0.7	
Non-biodegradable	kg	0.3	
Phosphorus	kg	0.029	
Potassium	kg	0.17	
Magnesium	kg	0.0091	

TABLE IV-13

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 02

Item: Feedlots

Process or Activity: Biodegraded Feedlot Waste

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	1.86	261
Volume	l -wet	0.58	
H_2O content (of wet weight)	%	58.0	
Combustible	kg	0.6	
Non-combustible	kg	0.4	
Ash content	kg	0.4	
Liquid form	kg		
Solid form	kg		
Energy content	kcal		
Oxygen requirements	kg BOD_5	0.15	
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg	0.6	
Non-biodegradable	kg	0.4	
Phosphorus	kg	0.045	
Potassium	kg	0.15	
Magnesium	kg	0.012	

"Best Practicable Control Technology Currently Available for the feedlot industry is containment of all contaminated liquid runoff resulting from rainfall, snowmelt or related cause and application of these liquids along with the generated solid wastes to productive cropland . . ."

In future years the percentage of agricultural wastes disposed of in non-productive manners should decline as reuse in fertilizers and newly-developing feed applications develops.

The data for ducks, horses, dogs, cats, etc. are scant. In addition, the runoff figures for all animal types are approximate since they depend on rainfall, feedlot design, and other factors. Due to these considerations, data in this sector can be given an overall confidence level of 1, indicating a 100 percent possible variation in the final predictions.

Summary.

Untreated Discharges. The pollutants generated as a result of housing animals in feedlots are mainly dry solids, BOD, ash, and nitrogenous wastes; these pollutants are either directly discharged into the water medium or removed via mechanical means. The two main sources of water pollutants in this sector are: milk rooms(for dairy cattle) and housing (barns, yards, etc. for all other animals); and storm drainage runoff. Total untreated solids generated from dirt lots were forecast to increase from 20,000 million kg in 1971 to 25,446 million kg in 1985; total untreated solids generated from solid and slotted floors were forecast to increase from 28,665 million kg to 30,264 million kg during the same period.

Treatment Methods and Reuse. Common waste-removal methods are mainly mechanical (e.g., scraping) and water flushing. Mechanical removal creates residues which are usually reclaimed; flushed wastes, along with drainage runoff, must undergo effluent treatment. These treatments, which all produce some solid waste residues, are mainly lagooning, oxidation ditches, activated sludge, and evaporation. Reuse is an important factor when considering solid waste generation from pollution control in feedlots. Of the various alternative disposal methods, land composting and other utilizations provide complete reuse, while feed recycling involves 80 percent reuse, dehydration 43 percent reuse, oxidation ditch refeed 25 percent, and incineration none.

Residues Created from Pollution Control: Types and Amounts. Total solid residues from pollution control in feedlots were forecast to increase from 920 million to 1,160 million kilograms between 1971 and 1985. In addition, a large amount of solids are not attributable to pollution control; these are derived from solids removed from animal manure with dry processes. They were forecast to decrease from 5,540 million kg in 1971 to 4,560 million kg in 1985. The main factor responsible for decreased removal residues is an estimated increase in solid waste reuse, and a corresponding decrease in landfill disposal between 1971 and 1985.

Raw solid waste residues from feedlots were estimated to be composed of about 84 percent water. Of the dry residue, approximately 70 percent is biodegradable, 30 percent is ash, 17 percent is potassium, three percent is phosphorus, and about one percent is magnesium.

SECTION V

THE MINING AND MILLING INDUSTRIES
SIC 10, 11, 12,and 14

Introduction.

The mining and milling of metals (SIC 10), anthracite coal (SIC 11), bituminous coal (SIC 12), and non-metals except fuels (SIC 14) produce large quantities of pollutant discharges both to air (primarily particulates) and water (suspended solids, acid and mineral water mine drainage). Some of these pollutants are hazardous wastes, such as radioactive tailings and heavy metal ions, which contaminate some process water.

The additional solid waste residues likely to be generated by proposed pollution controls are large in absolute quantity but small in comparison to the total volume of overburden and tailings already processed in mining and milling operations.

Untreated Discharge Factors.

Air Pollutants. The main air pollutant from the mining and milling industries is particulates (See Table V-1). Copper crushing has the highest particulate discharge rate (120.0 kg of pollutant per metric ton of output). Several other processes have discharge rates from 10 to 20 kg (limestone crushing, phosphate and gypsum milling, and lead and zinc crushing).

Particulate emissions from stationary equipment such as mine vents, ore grinders, and loading bins are adaptable to control equipment. Particulates generated over distributed activity sites (such as surface mines, storage piles, and tailing ponds) can only be controlled through effective engineering design. For that reason, it was not possible to estimate air pollution generated in open areas. Table V-1 refers only to activities occurring at equipment sites.

Certain mining and milling operations produce small amounts of radioactive air pollutants. Battelle[237] has estimated the quantity and composition of these pollutants and found that only insignificant amounts of noble gas radioisotopes are emitted. These are short-lived elements which can be safely released into the atmosphere after a short holding period. Radioactive air pollutants from mining and milling reactions are not included in the following solid waste residue estimates.

Water Pollutants. Water pollutants generated by the mining industries occur in drainage and process water; the pollutants in both are basically the same. Drainage water basically results from ground or surface water entering the mining area; it is pumped from the mine into tailing ponds or local streams. Process water is used in most mines, depending on the type of mine, type of ore, and availability of water. A few mines use solution extraction or acid baths, and these produce waters polluted with dissolved metals and acids in concentrations higher than normal for mines. Table V-2 presents the sources before treatment of water pollutants capable of producing solid waste.

TABLE V-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 10-12,14

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Iron crushing		kkg (product)	Particulates[b]	0.7	10
Copper crushing				120.0	
Lead crushing				10.0	
Zinc crushing				18.0	
Bauxite crushing				12.0	
Coal cleaning	Pneumatic	kkg (product)	Particulates	9.0	c
	Thermal drying			9.0	d
	-fluidized BOD			10.0	169
	-flash			8.0	169
	-multi-louvered			12.5	169
Stone quarrying	Overall	kkg (product)	Particulates	8.5	10
Sand & gravel quarrying		kkg (product)		0.05	10
Phosphate rock	All			18.5	e
Phosphate drying				7.5	169
Phosphate grinding				10.0	169
Phosphate handling				1.0	169
Gypsum milling	All	kkg (product)	Particulates	20.9	169
Gypsum drying				20.0	
Gypsum grinding				0.5	
Gypsum handling				0.35	

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[a] For 1971 or most recent available information.

[b] These values are converted from values for or by using the known ratio of ore to final product.

[c] Calculated from value for thermal drying.

[d] Weighted average of the three listed methods.

[e] Ignored 20 kg/kkg open pile figure which is not subject to pollution controls forming solid residues.

TABLE V-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 10-12,14

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Acid mine drainage		10^6 liters water	Acid as $CaCO_3$ or as H_2SO_4	367[b]	196, 197
			Total Fe	127[b]	
			Fe^{++}	32[b]	
			SO_4	1,050[b]	
			Ca as $CaCO_3$	233[b]	
			Mg as $CaCO_3$	168[b]	
		10^6 liters water	Heavy metals	n.d.	
Metal mining	Process water		Suspended solids	10	c
Coal mining				0.01	
Stone mining				0.01	
Acid mine drainage		kkg coal	Acid as $CaCO_3$ or as H_2SO_4	0.092	d
			Total Fe	0.032	
			Fe^{++}	0.009	
			SO_4	0.28	
			Ca as $CaCO_3$	0.055	
			Mg as $CaCO_3$	0.041	
			Heavy metals	n.d.	

[a] For 1971 or most recent available information.

[b] Median value, calculated from 5-area means in References 96 and 197.

[c] In-house estimate.

[d] Calculated from mean value of five representative coal mining areas. See Table V-3.

Many factors influence the quantity and composition of mine drainage, including ore, soil, groundwater, rainfall, type of mine, and local geology. Both dead and active mines produce drainage water, with dead mines producing somewhat more. Little data on mine drainage flows are available, however, because of great variability.

Acid mine drainage forms the overwhelming majority of mine pollution. Eastern coal mines produce most of the acid mine drainage, although other types of mines (iron, for example) produce significant quantities. Table V-3 shows the average drainage composition of five coal mine areas. The pollution mechanism is fairly straightforward; pyrite (FeS_2) found in soil and coal or ore is oxidized by exposure to air into $FeSO_4$ and H_2SO_4. Other pollutants, such as heavy metal ions, are leached by these acid waters. The oxidation of pyrite is the first step, and this occurs when a previously unexposed pyrite comes to the ground surface, as in mining. Pyrites are typically found in coal-bearing formations.

This Section focuses on acid mine drainage from coal mines because it is the major source and has been quantitatively studied. Active mines are estimated to account for 40 percent of acid mine drainage, dead underground mines 35 percent, and dead surface mines 25 percent. Acid mine drainage was estimated for 1968 at 3.3 kkg per year.[407] Table V-4 summarizes mining activities and related air and water pollution controls.

Since mining techniques will probably not change significantly by 1985, the annual pollution from active mines should closely follow annual production. Since the number of dead mines will increase, the amount of pollution from them will increase, but at a rate determined by factors other than production--mine deaths, use of seals and cover-soil plantings and mine rebirths. Drainage from dead mines will be prevented rather than treated so that these waters are not potential sources of solid residues.

Process water is used in most mines for extraction, transportation, or cleaning. Used water typically flows into tailing ponds (large, flat, shallow basins where suspended solids settle out.) Western mines, facing a constant water shortage, mostly recycle water from tailing ponds. But Eastern mines mostly neutralize and release this water.[296] Whether the process water is recycled or released does not affect the quantity of solid residues to a significant degree. The important point is that process water is subject to settling in tailing ponds, where large quantities of suspended solids settle. These ponds are eventually covered and planted when filled.

No estimates for quantity of process water or for quantity of suspended tailings therein were available, even though both amounts are likely to be very large. Mines produce most amounts of solid waste in the form of excavated overburden and ore tailings; the ratio of product to solid waste typically falls into the range of 1:100 to 1:300. An estimate for the quantity of suspended solids per unit of ore was necessary to estimate the solid residues in process waters. Metal mining produces approximately 10 kg of tailings per kg of metals. This follows from the ratio of total ore mined to the metal produced, since tailings are produced when concentrating the ore prior to smelting.

TABLE V-3
AVERAGE COMPOSITION OF POLLUTANTS FROM COAL MINING IN FIVE ACID WATER DRAINAGE AREAS

Item (mg/l)[a]	St. Clair,[196] Penna.	Osceola Mills,[196] Penna.	Bennett Branch,[196] Hollywood, Penna.	Proctor 2,[196] Hollywood, Penna.	Grassy Run,[197] West Va.
Total Fe	25	159	-	653	93
Fe++	25	45	-	445	20
Sulfate	620	2,665	1,480	-	612
Ca	250	410	185	233	211
Mg	450	270	70	168	93

[a] Median:

Total Fe = 127, Fe^{++} = 32, sulfate = 1,050, Ca = 233, mg = 168

TABLE V-4

MINING ACTIVITIES AND RELATED AIR AND WATER POLLUTION CONTROLS

Operation	Location	Pollution Control Processes[a]
Extraction	Surface or strip mine	C,D,E
	Underground mines	A,B,C,D,E
Transportation	Conveyor	A
	Rail car	A
	Tractor-trailor	A
	Water sluice	C,E
Concentration	Crushing	A
	Water bath	C,E
	Air bath	A
	Thermal drying	A
	Acid bath	C,E

[a] Legend for pollution control processes:

A. Cyclones, baghouses, wet scrubbers
B. Seals, bulkheads
C. Limestone, other neutralization treatments
D. Soil cover, grading, plantings
E. Settlement ponds, clarifiers, floculators

Iron is from 10 to 40 percent in ore while copper, zinc, and lead range from 0.5 to 10 percent in ore, with the mean for copper around 1 percent. Coal washing produces anywhere from 1 to 5 percent suspended solids when washing with water, but less than half the coal mined is washed. An average of 1 percent or 0.01 kg per 1 kg of coal is probably close.

The confidence level of the untreated air pollutant discharge rate is 3, indicating a possible 25 percent variation in the data. The confidence level of the water pollutant discharge rate, due to less extensive published data, is 2, indicating a possible 50 percent variation in the data.

Industry Description and Schematic.

Mining activities consist of ore extraction, transportation, and concentration; each of these activities can be performed by several alternative processes. Various alternative locations of extraction., transportation,and concentration activities are listed in Table V-5, which also lists pollution control processes often employed at these locations.

The optimal choice depends on the ore, geology, water, and topology. Basic physical methods are used except where low ore concentrations or other difficulties are encountered. Coal mining uses mechanical extraction and handling, with only 49 percent cleaned, since coal is found in relatively pure veins. In contrast, copper and related metals found in the same veins are often acid leached from clays and ores as low as 0.5 percent metal. Figure V-1 illustrates the basic steps involved in coal mining and milling.

Economic Forecasts.

Federal and industrial estimates of 1971 mine production are presented in Table V-5. Annual growth factors are used to forecast production for selected years through 1985. These growth rates have been listed for metal, coal, and stone mining.[68] Table V-6 presents estimated production through 1985 for all major and most minor mining industries. The confidence level for the data in this section is 3, indicating a possible 25 percent variation in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table V-7 presents pollutants and quantities generated during each forecast year. The main pollutant classes are particulates and suspended solids. Radioactive tailings, a suspended solids water pollutant from uranium milling, are a hazardous waste; treatments are further discussed in Section XIX, which deals with hazardous wastes. Acid mine drainage quantities are based on an estimate of 3.6×10^6 kg of solids in 1971,[141] compounded by the annual growth rate estimate for coal mining. Quantities of other pollutants are based on emission factors from Tables V-1 and V-2 multiplied by annual production estimates from Table V-6. Radioactive tailings (from Section XIX on hazardous wastes) are based on the Battelle report.[237]

TABLE V-5
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 10-12,14

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Iron	All	10^6 kkg			82.1				402	1972
Copper					1.4					
Lead					0.5					
Zinc					0.5					
Gold					0.000046					
Silver					0.0013					
Bauxite					2.0					
Magnesium					0.11					
Manganese					0.001					
Chromite					0.0					
Molybdenum					0.050					
Nickel					0.014					
Uranium					0.012					
Vanadium					0.005					
Mercury					0.00059					
Tin					0.0					
Titanium					0.62					
Anthracite coal		10^6 kkg			8.7				402	1972
Bituminous coal					501				402	1972
Bituminous coal					501	612	708	785	68	1972
Dimension stone		10^6 kkg	1970	1.45	1.45				315	1972
Crushed stone	Production			795.0	793.2				315	1972
			1972	680.6	635.6				284	1972
			1973	698.7					284	1972
			1972	840.3	800.4			1,189	285	1973

TABLE V-5 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 10-12,14

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Sand and gravel	Production	10^6 kkg	1970	856.5	834.5				316	1972
			1972	826.1	839.4				284	1972
			1973	871.1					284	1972
			1972	901.1	858.4			1,370	285	1973
	Consumption		1972	862.1	834.8				287	1972
			1973	889.3						
Clays (all)		10^6 kkg	1970	49.7	51.5				317	1972
Clay and shale		10^6 kkg	1970	36.0	40.6				317	1972
Kaolin		10^6 kkg	1970	4.4	4.4				317	1972
Kaolin	Total demand	Index (1967=100)	1972	105.0	100.0				289	1973
			1973	110.3						
Fine clay		10^6 kkg	1970	5.9	2.7				317	1972
Bentonite		10^6 kkg	1970	2.3	2.45				317	1972
Fuller's earth		10^6 kkg	1970	0.89	0.92				317	1972
Bale clay		10^6 kkg	1970	0.64	0.54				317	1972
Chemical and fertilizer		10^6 kkg			63.0				317	1972
Fluorspar		10^6 kkg	1970	0.244	0.246				410	1972
			2000	0.250					300	1973

TABLE V-5 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 10-12,14

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Potash	K_2O equiv.	10^6 kkg	1970	2.45	2.35				318	1972
			1972	3.08			2.72		302	1972
			1973	3.18					302	1972
Phosphate rock	Production (P_2O_5 content)	10^6 kkg	1970	10.9	11.0				319	1972
	Consumption increase	Percent	1972-77	+4.5					304	1973
Rock salt		10^6 kkg	1970	41.6	40.0				410	1972
Sulfur	Total production		1970	9.72					320	1972
			1970	9.65				11.99	225	1972
Gypsum	Crude	10^6 kkg	1970	8.5	9.43				404	1972
	Crude			7.74				8.97	225	1972
	Calcined			6.96	7.84				323	1972
Talc, soapstone, pyrophyllite		10^6 kkg	1970	0.93	0.94				404	1972
Pumice and pumicite		10^6 kkg	1970	2.49	2.73				321	1972
			1973	2.8	2.7				284	1972
Asbestos		10^6 kkg	1970	102.9				163.0	225	1972
				102.9	107.8				410	
Perlite		10^6 kkg	1970	0.42	0.39				410	1972

TABLE V-5 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 10-12,14

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Metal mining	Annual growth rate	Percent			3.1	3.1	3.1		68	1973
Coal mining					2.9	2.9	2.9			
Stone mining					3.7	3.7	3.7			

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[a] 1967 is the index base (i.e. 1967 production = 100).

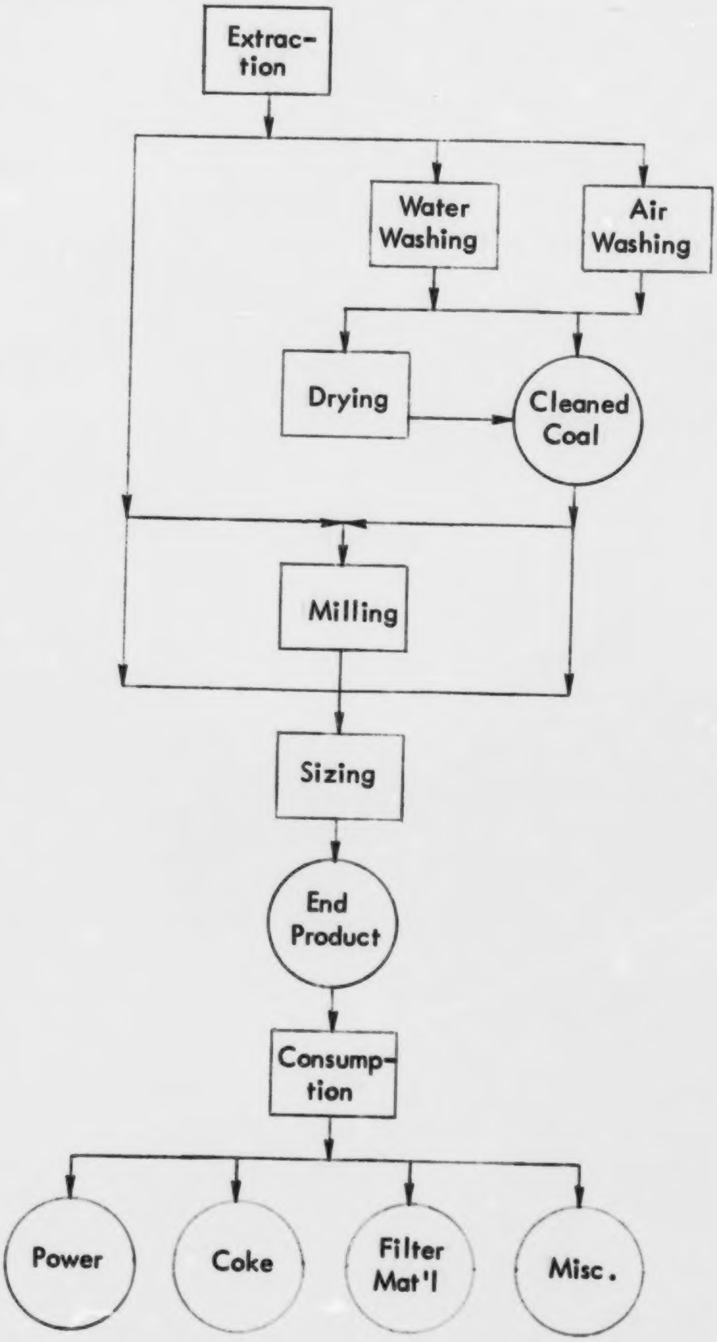
Extraction
Water Washing
Air Washing
Drying
Cleaned Coal
Milling
Sizing
End Product
Consumption
Power
Coke
Filter Mat'l
Misc.

FIGURE V-1
INDUSTRY SCHEMATIC:
COAL MINING

TABLE V-6
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 10-12,14

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Iron		10^6 kkg	82.1	402	92.8	a	108	a	125	a
Copper			1.4		1.6		1.8		2.1	
Lead and zinc			1.0		1.1		1.4		1.5	
Lead			0.5		0.6		0.7		0.8	
Zinc			0.5		0.6		0.7		0.8	
Gold			0.000046		0.000051		0.000066		0.000071	
Silver			0.0013		0.0015		0.0018		0.0020	
Bauxite			2.0		2.3		2.6		3.1	
Chromite			0		0		0		0	
Magnesium			0.11		0.12		0.16		0.17	
Mangenese			0.001		0.001		0.001		0.002	
Molybdenum			0.050		0.056		0.066		0.077	
Nickel			0.014		0.016		0.018		0.021	
Mercury			0.00059		0.00066		0.00078		0.00090	
Uranium			0.019		0.014		0.016		0.018	
Radium			n.d.							
Vanadium			0.005		0.006		0.007		0.008	
Tin			0		0		0		0	
Titanium			0.62		0.70		0.82		0.95	
Anthracite coal			8.7	402	9.8	a	11	a	13	a
Bituminous coal			501	68	612	68	708	68	785	68
Dimension stone			1.5	315	1.7	a	2.1	a	2.5	a
Crushed stone			793	315	917	a	1,100	a	1,320	a

TABLE V-6 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 10-12,14

Fluorspar

Item	Process or Activity	Physical Units (Metric)	1971 Quantity	1971 Ref. No.	1975 Quantity	1975 Ref. No.	1980 Quantity	1980 Ref. No.	1985 Quantity	1985 Ref. No.
Limestone		10^6 kkg	571	286	660	a	792	a	950	a
Sand/gravel			839	284	970		1,160		1,400	
Clays			52	317	60		72		86	
Fluorspar			0.25	410	0.29		0.35		0.42	
Potash			2.4	318	2.8		3.3		4.0	
Phosphate rock			11	319	13		15		18	
Rock salt			40	410	46		55		67	
Sulfur			9.7	320	11		13		16	
Gypsum			9.4	404	11		13		16	
Talc, soapstone, pyrophyllite			0.94	404	1.1		1.3		1.6	
Asbestos			108	410	129	b	154	b	180	225
Perlite			0.39	410	0.45	a	0.54	a	0.64	a
Pumice/pumicite			2.7	321	3.1	a	3.7	a	4.5	a

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[a] Uses average growth rate from Table 2: metal mining annual growth is 3.1 percent; coal mining annual growth is 2.9 percent; stone mining annual growth is 3.7 percent.[68]

TABLE V-7
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 10-12,14

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
AIR POLLUTANTS						
Particulates:						
Iron crushing		10	57	65	76	88
Copper crushing			170	190	220	250
Lead crushing			5	6	7	8
Zinc crushing			9	11	13	14
Bauxite crushing			24	28	31	37
Subtotal			265	300	347	397
Coal cleaning		169	630[b]	770[b]	890[b]	990[b]
Crushed stone		10	6,700	7,800	9,400	11,000
Sand and gravel quarrying		10	42	49	58	70
Phosphate rock		169	200	240	280	330
Gypsum processing		169	200	230	270	330
Asbestos		a	a	a	a	a
Total			8,037	9,389	11,245	13,117
WATER POLLUTANTS						
Suspended solids:						
	Acid mine drainage					
	-total	141	3,600	4,000	4,700	5,400
	-active	141,407	1,440	1,600	1,900	2,100
	-dead underground	141,407	900	1,000	1,200	1,300

TABLE V-7 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 10-12,1

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Suspended solids: (Cont.)						
	Acid mine drainage					
	-dead surface mine	141,407	1,260	1,400	1,600	1,900
	Tailing ponds:	c				
	-metals mining		8×10^5	9×10^5	11×10^5	13×10^5
	-coal mining		5,000	6,000	7,000	8,000
	-stone and clay mining		17,000	20,000	24,000	28,000
	Total		8×10^5	9×10^5	11×10^5	13×10^5
Radioactivity:						
	Tailings	237	1,100 ($.21 \times 10^4$Ci)	6,600 (1.2×10^4Ci)	18,000 (3.4×10^4Ci)	33,000 (6.3×10^4Ci)

---

[a] Very large but easily controlled.

[b] Based on the fact that 49 percent of all coal produced is cleaned.

[c] See text for estimate basis.

The values for uncontrolled air pollution discharges do not include pollutants generated from distributed activity sites, as no pollution control equipment exists capable of controlling these emissions (thus there are no solid residues from control).

The confidence level for the data in this section is 2, indicating a possible 50 percent variation in the data.

Likely Pollution Treatment Processes.

Table V-8 describes likely pollution control processes for mining operations. Particulates and suspended solids are, respectively, the main air and water pollution discharges from mining and milling. The mean particle size of both pollutants from this industry is relatively large, resulting in high efficiencies for pollution control equipment. The values listed in Table V-8 reflect this fact. In practice, however, a part of the particulates and suspended solids settles out before pollution control. This gravity settling of large particulates is the reason that the percent solid residues will not be as high as pollution treatment efficiencies would indicate. No major advances in pollution control technology are predicted for the mining and milling industries between 1971 and 1985.

Air Pollution Control. Cyclones and baghouses are the principal air pollution controls currently in use. Wet scrubbers are often used when the solid residues are not reusable. Suspended solids in scrubber water are then subject to water pollution treatments, as described below. The recent trend in the industry toward greater use of baghouses (about 99 percent efficiency) is forecast to continue, so that by 1980 about half of the air pollution controls should include baghouses. Overall efficiency is forecast to increase to about 85 percent in 1985, up from 80 percent in 1975 when cyclones will still be used predominantly.

Water Pollution Control. Effective design is an important pollution control in mining and milling. Isolating operations from wind and water is one such way of preventing pollution. Dead mine acid drainage can be reduced through passive controls such as bulkheads, waterstopping coatings, levees, cover soil, and plantings. The control of rain runoff and wind erosion can significantly reduce pollution from active mines. Effective design can significantly reduce pollutant emissions; such control does not generate solid residues.

Sedimentation in tailing ponds, followed by limestone neutralization and further sedimentation, is the currently used advanced water treatment.

Water treatment is predicted to continue with current procedures, beginning with large, shallow settling ponds where about 85 to 99 percent of the tailings settle out. The second step, already in use, will usually be limestone or limestone-lime neutralization. In this process, about 95 percent of the suspended metals and minerals remaining from the settling ponds are removed. Limestone consumption is the reason for settling before neutralizing. Alternatives to limestone are reverse osmosis, electrodialysis, and ion

TABLE V-8

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 10-12, 14

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Ore crushing & stone processing	All	Particulates	Cyclone	70-85	1		a
			Baghouse	95-99	1		b
Coal cleaning	All		Wet cyclone	95-99	1		b
			Cyclone	70-85	1		169
Mining process water	All	Suspended solids	Sedimentation/ limestone neutralization	99	1		b
Acid mine drainage	All		Sedimentation/ limestone neutralization	95	2		b
Uranium milling	All		Sedimentation/ limestone neutralization	90	1		237

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[a] Estimated from particle sizes ranging from 10 to 50+ (see attached).

[b] Standard efficiencies of current methods; variations will be insignificant within the confidence level of final residue values.

exchange, but limestone is the current overall best method.

The ratio of residues to suspended solids in acid mine drainage is approximately 2, the specific value being a function of local geology. This ratio follows from the reactions occurring when acid drainage is neutralized and the concentrations of the initial reactants. The major reaction is shown below in Equation V-1.

$$(V\text{-}1)\quad SO_4^{-2} + CaCO_3 \rightarrow CaSO_4 + CO_3^{-2}$$

The weight ratio of SO_4^{-2} to $CaSO_4$ is 96:136. Fifty percent beyond the stochiometric quantity of limestone is used so that the ratio of suspended SO_4^{-2} to residues is 96:186 or 1.9.

These same reactions occur in neutralization of process water, but neutralization is the second step after sedimentation of most suspended solids, so that the overall increase is lower.

The confidence level for the data in this section is 3, indicating a possible 25 percent variation.

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Reuse in mining operations depends on the product being mined. Based on literature and personal communications,[296] estimates have been made for the metal, coal, and stone mining and milling industries. Metal mining operations produce pollutants of no commercial value so that reuse is zero. Coal cleaning produces two distinct residues. The dust from air washing is valueless, but dust from thermal drying after water washing is often reclaimed. Approximately 49 percent of all coal mined is cleaned; 7 percent of that is air-washed and 93 percent is wet-washed. About 21 percent of wet-washed coal (20 percent of all coal cleaners) is thermally dried. Since air washing and thermal drying emit pollution at the same rate, the ratio of 20 to 27 is the percent reused. Solid residues from air pollution control in stone and mineral operations are about 90 percent reused. This mainly reflects the high reuse for limestone, sand, and clay, and the fact that the three account for over ninety percent of stone and mineral production. The confidence level for the data in this section is 2, indicating a possible 50 percent variation. Table V-9 summarizes the above information.

Total Impact on Solid Residues of Pollution Treatment Processes.

Tables V-10 through V-13 list significant solid residues from pollution control in mining operations. The quantity of solid residues from process water is very large; these wastes are tailings from milling operations. Other solid residues have an effect on solid waste management much greater than their relative weight would indicate. The waste from air pollution control requires special handling equipment for disposal. The disposal of radioactive tailings requires long-term surveillance and environmental isolation. Figure V-2 illustrates an air and water pollution treatment schematic for bituminous coal and lignite mining, and Figure V-3 shows a water pollution treatment schematic for limestone neutralization mining wastes.

TABLE V-9
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 10-12, 14

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Particulates					
-coal cleaning		Air wash	0	89	Soil-like
		Thermal drying	100	89	Coal dust
-stone and mineral milling		Cyclone	90	296	Estimate particulates of product
		Baghouse	90	296	Estimate particulates of product
-metal ore milling		Cyclone or baghouse	50	296	Some fines back to fine ore pile

TABLE V-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 10-12, 14

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Metal ores	Milling	Cyclones, baghouses	50	140	80	110	50	60
Coal cleaning	Milling	Cyclones, baghouses	75	470	90	420	25	110
Stone crushing	Milline	Cyclones, baghouses	50	3,370	80	2,700	10	270
Phosphates	Milling	Cyclones, baghouses	50	100	80	80	10	10
Gypsum	Milling	Cyclones, baghouses	50	100	80	80	10	10
Total Residues from Air Pollution Control:				4,180	81	3,390	14	460
WATER POLLUTANTS								
Acid mine drainage	Dead mines	Passive control	10	0				
	Active mines	Limestone	10	280	95	270	100	270
Process water	All mines	Sedimentation	100	8×10^5	98	8×10^5	100	8×10^5
Radioactivity:								
Tailings	All mines	Sedimentation/ limestone	100	1,100	90	990	100	990
Total Residues from Water Pollution Control:				8×10^5		8×10^5		8×10^5
Total Residues from Air and Water Pollution Control:				8×10^5		8×10^5		8×10^5

TABLE V-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 10-12,14

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Metal ores	Milling	Cyclones, baghouses	75	230	80	180	50	90
Coal cleaning	Milling	Cyclones, baghouses	100	770	95	730	25	180
Stone crushing	Milling	Cyclones, baghouses	75	5,850	80	4,680	10	470
Phosphates	Milling	Cyclones, baghouses	75	180	80	140	10	10
Gypsum	Milling	Cyclones, baghouses	75	180	80	140	10	10
Total Residues from Air Pollution Control:				7,210	81	5,870	13	760
WATER POLLUTANTS								
Acid mine drainage:	Dead mines	Passive control	10	0				
	Active mines	Limestone	25	800	95	760	100	760
Process water	All mines	Sedimentation	100	9×10^5	99	9×10^5	100	9×10^5
Radioactivity:								
Tailings	All mines	Sedimentation/ limestone	100	6,600	90	5,940	100	5,940
Total Residues from Water Pollution Control:				9×10^5		9×10^5		9×10^5
Total Residues from Air and Water Pollution Control:				9×10^5		9×10^5		9×10^5

TABLE V-12
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 10-12,14

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Metal ores	Milling	Cyclone, bag.	100	350	85	300	50	150
Coal mining	Milling	Cyclone, bag.	100	890	98	870	25	220
Stone crushing	Milling	Cyclone, bag.	100	9,460	85	8,040	10	800
Phosphates	Milling	Cyclone, bag.	100	280	85	240	10	20
Gypsum	Milling	Cyclone, bag.	100	270	85	230	10	20
Total Residues from Air Pollution Control:				11,250	86	9,680	12	1,210
WATER POLLUTANTS								
Acid mine drainage	Dead mines	Passive control	60	0				
	Active mines	Limestone	65	2,470	95	2,350	100	2,350
Process water	All mines	Sedimentation	100	1.1×10^6	99	1.1×10^6	100	1.1×10^6
Radioactivity:								
Tailings	All mines	Sedimentation, limestone	100	18,000	90	16,200	100	16,200
Total Residues from Water Pollution Control:				1.1×10^6		1.1×10^6		1.1×10^6
Total Residues from Air and Water Pollution Controls:				1.1×10^6		1.1×10^6		1.1×10^6

TABLE V-13
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 10-12,14

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Metal ores	Milling	Cyclone, bag.	100	400	85	340	50	170
Coal cleaning	Milling	Cyclone, bag.	100	990	98	970	25	240
Stone crushing	Milling	Cyclone, bag.	100	11,070	85	9,410	10	940
Phosphates	Milling	Cyclone, bag.	100	330	85	280	10	30
Gypsum	Milling	Cyclone, bag.	100	330	85	280	10	30
Total Residues from Air Pollution Control:				13,120	86	11,280	12	1,410
WATER POLLUTANTS								
Acid mine drainage	Dead mines	Passive control	70	0				
	Active mines	Limestone	75	3,150	95	2,990	100	2,990
Process water	All mines	Sedimentation	100	1.3×10^6	99	1.3×10^6	100	1.3×10^6
Radioactivity:								
Tailings	All mines	Sedimentation, limestone	100	33,000	90	29,700	100	29,700
Total Residues from Water Pollution Control:				1.3×10^6		1.3×10^6		1.3×10^6
Total Residues from Air and Water Pollution Control:				1.3×10^6		1.3×10^6		1.3×10^6

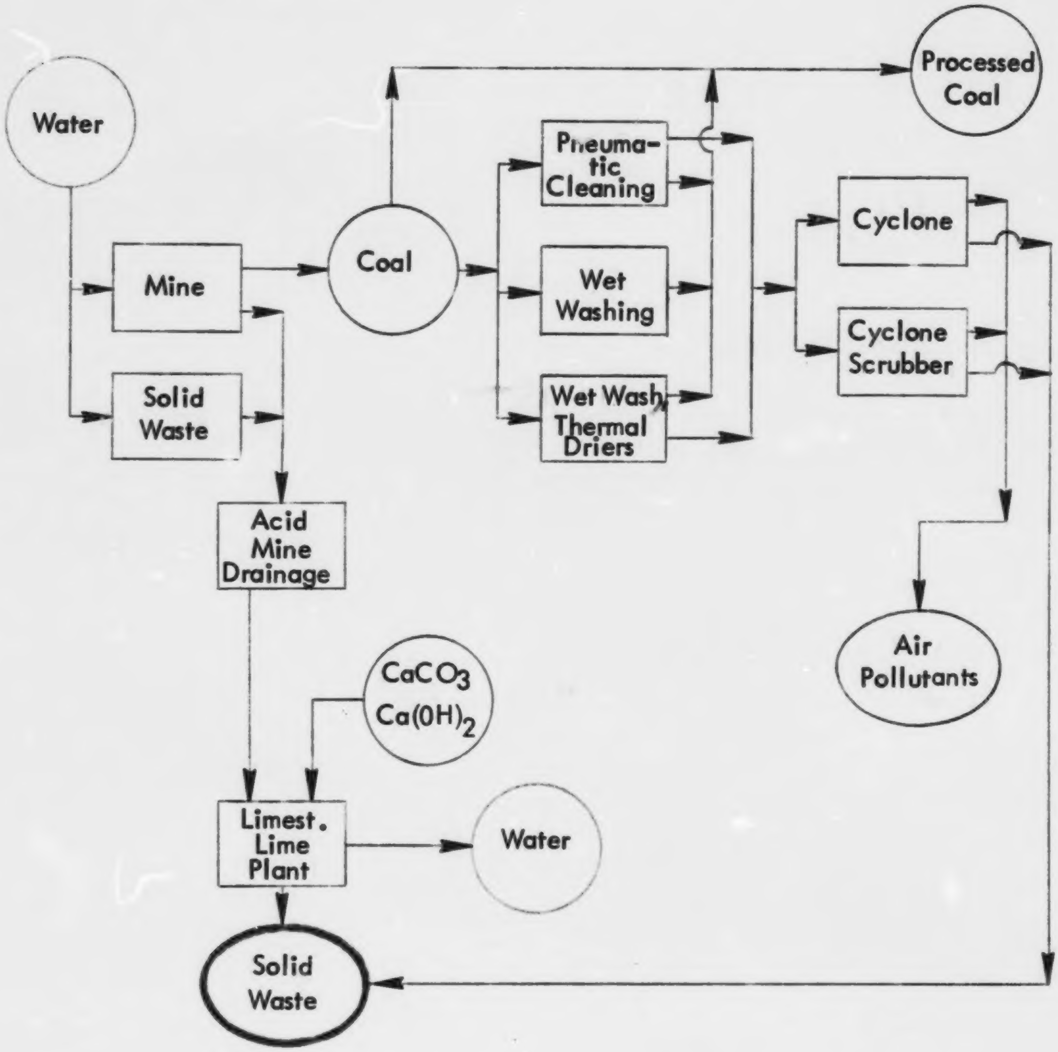
Water
Mine
Solid Waste
Coal
Processed Coal
Pneumatic Cleaning
Wet Washing
Wet Wash Thermal Driers
Cyclone
Cyclone Scrubber
Air Pollutants
Acid Mine Drainage
CaCO3
Ca(OH)2
Limest. Lime Plant
Water
Solid Waste

FIGURE V-2
AIR AND WATER POLLUTION
TREATMENT SCHEMATIC:
BITUMINOUS COAL AND LIGNITE MINING

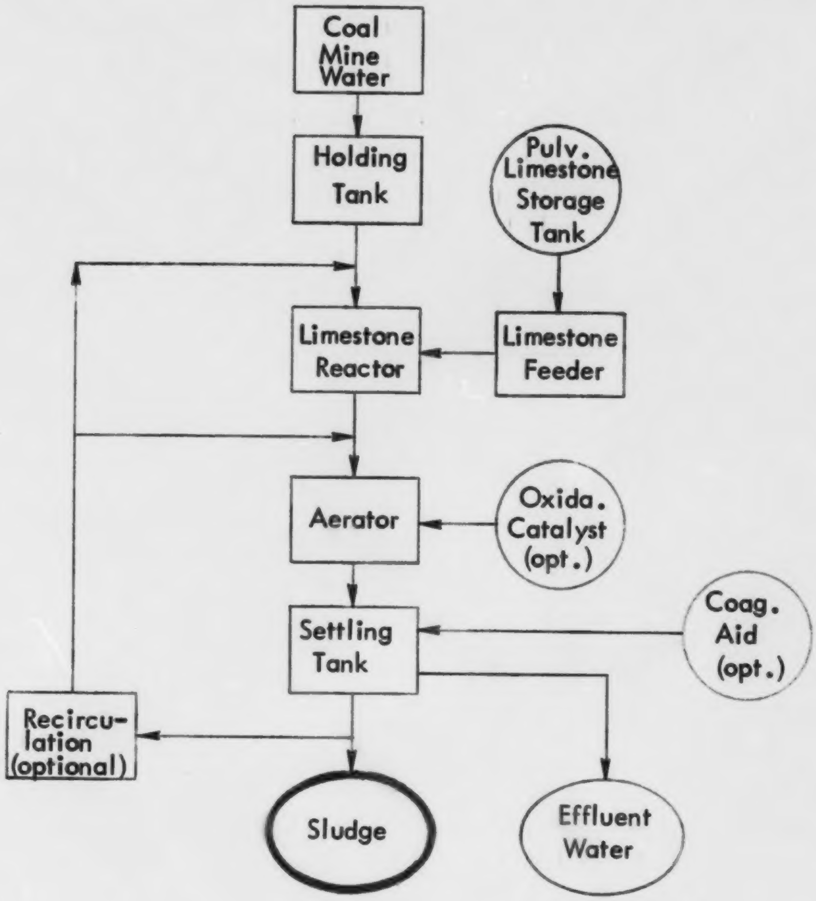
Coal Mine Water
Holding Tank
Pulv. Limestone Storage Tank
Limestone Reactor
Limestone Feeder
Aerator
Oxida. Catalyst (opt.)
Settling Tank
Coag. Aid (opt.)
Recirculation (optional)
Sludge
Effluent Water

FIGURE V-3
WATER POLLUTION TREATMENT SCHEMATIC:
LIMESTONE NEUTRALIZATION
MINING WASTES

The residues from advanced water treatment (basically limestone neutralization) are very small in proportion to the total quantity of tailings although large in comparison to residues from the pollution controls. The important comparison is with tailings already settled in tailing ponds, in which case the extra residues from advanced water treatment are insignificant.

Some solid residues from acid mine drainage and tailings contain heavy metals and are therefore hazardous. These residues have not been separately analyzed from non-hazardous residues because no reliable information exists on heavy metals which would permit a reasonably accurate estimate.

Confidence level for the data in this section is 3, indicating a possible 25 percent variation in the data. The variation is lower than in many other industries because of the very large contribution of tailings to total solid residues, the estimate for which is within 20 percent of the actual figure.

Composition of Solid Waste Residues.

The solid waste residues not recycled are of two distinct types: sludges and silicates. Sludges are the result of limestone neutralization. "Silicates" refers to the non-organic soils and rocks usually excavated with the ore. Sludges contain high concentrations of metallic oxides, calcium sulfate, and silicates. Sludges are subject to leaching and require isolation. Most tailings and air pollution residues not reused are silicates. These wastes are inert except in isolated cases. Of course "silicates" are a common term for a highly complex waste that contains considerable silicate.

Some mines produce cyanides, arsenates, and heavy metals. Their weight is insignificant in comparison to the total volume of solid wastes, but where they occur they occur in hazardous concentrations.

The confidence level for the data in this section is 2, indicating a possible 50 percent variation in the data. This applies only to the trace elements, however. Data such as the combustible content of mining wastes are nearly exact because of the detailed knowledge which exists of the inorganic content of the wastes.

Factors Affecting Quality of the Data.

Production estimates are more accurate than the emission estimates. Their accuracy is within 10 to 20 percent for 1971, declining with subsequent years to within 20 to 40 percent for 1985. Estimates for the major solid residues identified vary in accuracy. The estimates for suspended solids in process water are very rough, being averages of diverse processes and industries. Estimates of annual quantities are within a factor of 100. Estimates for listed residues are far more accurate than for process waters, but are only within a factor of 10. Probably the best estimate is for radioactive tailings because the industry is small, isolated, and well documented. Due to the previously mentioned sources of inaccuracy in data concerning mining operations, the overall confidence level for predictions in this Section is 2, indicating a possible 50 percent variation.

Summary.

Untreated Discharges. Particulate emissions in mining and milling operations are very large. Total emissions before treatment are forecast to increase from 8,000 million kg in 1971 to 13,100 million kg in 1985. Huge amounts of suspended solids are discharged before treatment. Tailing ponds have been in common use long enough so that partial SS control is an accepted practice in the industry. Suspended solids before treatment are forecast to increase from 8×10^{11} kg in 1971 to 13×10^{11} kg in 1985. Both process water and drainage water contribute to this pollutant load, but the tailing pond influent accounts for most of these residues.

Treatment Methods and Reuse. Cyclones and baghouses are the most common air pollution control devices, although wet scrubbers are utilized in some milling operations. Sedimentation in tailing ponds removes the overwhelming portion of suspended solids discharged by mines, and neutralization followed by sedimentation is used to treat acid mine drainage. Neutralization creates approximately 2 kg residues for every kg of acid neutralized. Passive controls entail the sealing of "dead" mines to prevent the discharge of drainage waters.

The degree of reuse of solid residues from air and water pollution control is a function of mine type, product quality, etc. Metal mines typically do not recycle residues while coal cleaning produces both usable and solid waste residues. Normally, dust collected from non-metal mining can be reused. Normal practice is for it to be dumped onto the fines pile.

Residues Generated from Pollution Control: Type and Amounts. Total solid residues from air and water pollution control in mines and ore milling operations are forecast to increase from 8×10^{11} kg in 1971 to 1.3×10^{12} kg in 1985. Most of these solid waste residues stem from tailing ponds. This tends to obscure the very significant quantities of solid waste residues from air pollution control and drainage from dead mines. Waste residues from air pollution control are forecast to increase from 510 million kg in 1971 to 1,500 million kg in 1985. The impact of total solid wastes is not as important as it seems from the quantities involved, as they are produced near mines which are natural disposal sites. In essence they are a result of only moving solids a few feet from their original location. The mined areas provide a natural land disposal site. Strip mines may be backfilled immediately; backfilling of underground mines must wait until their ore content has been exhausted. The cost of reclaiming strip mined land is not small, however, and so the solid wastes have a significant economic impact. The heavy metal content of solid wastes from mine air and water pollution control gives some of these residues a capability to create toxicity problems in water through leaching of disposal sites.

SECTION VI

MEAT AND DAIRY PRODUCTS
SIC 201, 202

Introduction.

The Meat and Dairy Products Industry is a significant contributor to water pollution. Industry wastes are largely organic, however, and are readily bio-degraded. Only a few minor production and manufacturing processes in this industry generate air pollutants. Smoking of meat contributes approximately 0.15 kg per metric ton of meat smoked, but only a small percentage of meat produced is smoked. Some noxious but minor air pollution is caused by rendering and other food plant processing odors. The Meat and Dairy Industry contributes approximately 19 percent of all National discharges of BOD_5 and 6.4 percent of all National discharges of suspended solids; 95 percent of these discharges are accounted for by the meat industry.[11] Although the majority of pollutants are removed by in-plant primary industrial waste treatment works, these treatment facilities do not contribute greatly to solid wastes because of the high degree of reuse of the suspended solids residues. Most of these solid residues are valuable fats and proteins which are combined with meat scraps at rendering plants for reclamation into marketable animal feeds. Secondary wastewater treatment processes yield a larger proportion of non-reusable solid wastes due to the nature of the chemical and biological treatments,and such residues and sludges must be disposed to landfills.

Untreated Discharge Factors.

Air Pollutants. Particulates from smoking meat are the main source of air pollutants from the Meat and Dairy Products Industry. Certain hydrocarbons are also created along with particulates. The contribution of smoking to total particulate discharges is unknown because of uncertainty regarding the quantity of meat smoked. The smoked meats are a relatively minor production factor in the total industry. (See Table VI-1).

Water Pollutants. The Meat and Dairy Products Industry is highly complex, with many plant types, products, and manufacturing process steps. Most of these elements are cited separately in Tables VI-1 and VI-2,which estimate untreated air and water emissions, respectively. The majority of the waste stream is created during the slaughtering process and by-product handling. Table VI-2 underestimates the "uncontrolled" discharges by at least 18 percent for poultry and 44 percent for meat, since it assumes the raw waste streams for meat and poultry are from plants which have already removed floating or settleable solids from the wastewater stream. These factors were derived from the discharges of plants using old technology in 1967.[258] Even the old technology assumed floatables such as feather removal and offal separation for poultry. Since most of these residues can be reclaimed for animal feed, no large impact on solid waste residues from water pollution control is expected. Also, even older plants with inefficient waste management technologies do not release all such materials into the water; hence their inclusion as water pollutants could overstate the solid waste residues produced.

TABLE VI-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Red meat smoking		kkg meat	Particulates	0.15	169
			Hydrocarbons (CH_4)	0.035	

TABLE VI-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201,202

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Red meat products:					
Viscera handling	Tripe processing Other	1,000 kg killed	Grease	3.6	290
Holding pens			Nitrogen	1.3	
Cutting	Bone saws		Phosphorus	0.33	
Rendering	Dry		Suspended solids	2.8	
	Wet		BOD_5	2.0	
Blood processing	Coagulated or centrifuged		BOD_5	1.5	
	Dried whole			0.5	
Hide processing	Curing		Chlorides	15.6	
			BOD_5	2.5	
Paunch handling	Wet dumping		Suspended solids	5.6	
			BOD_5	2.5	
Hair processing	Hydrolyzing		Suspended solids	0.1	
	Washing			2.0	
Clean-up	Dry clean		BOD_5	0.1	
	Wet wash			3.0	
Slaughtering			BOD_5	4.0	
Simple slaughterhouse[b]		kkg LWK[a]	BOD_5	6.0	290
			SS	5.6	
			Grease	2.1	
			Kjeldahl N	0.68	
			Cl	2.6	
			Total P	0.05	
			Wastewater	7,379 (liters)	

TABLE VI-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Complex slaughter-house[c]		kkg LWK	BOD$_5$	10.9	290
			SS	9.6	
			Grease	5.9	
			Kjeldahl N	0.84	
			Cl	2.8	
			Total P	0.33	
			Wastewater	7,379 (liters)	
Low-processing[d] packinghouses		kkg LWK	BOD$_5$	8.1	290
			SS	5.9	
			Grease	3.0	
			Kjeldahl N	0.53	
			Cl	3.6	
			Total P	0.13	
			Wastewater	7,842 (liters)	
High-processing[e] packinghouses		kkg LWK	BOD$_5$	16.1	290
			SS	10.5	
			Grease	9.0	
			Kjeldahl N	1.3	
			Cl	15.6	
			Total P	0.38	
			Wastewater	12,514 (liters)	
Meat packing houses	Old technology	kkg	BOD$_5$	26.9	258
	Advanced technology			15.1	
	Net in plant reduction			11.8	
	$\frac{\text{Adv.}}{\text{Old}} \times 100$	percent	n.a.	56.0	

TABLE VI-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Poultry Products:					
Processing		kkg LWK	BOD_5	7.0	258
			SS	3.5	f
			Grease	5.9	g
			Kjeldahl N	0.84	g
			Cl	2.8	g
			Total P	0.33	g
			Wastewater	7,379 (liters)	g
Poultry packing houses	Old technology	1,000 birds	BOD_5	14.4	258
	Advanced technology			11.8	
	Net in plant reduction			2.6	
	$\frac{Adv.}{Old}$ x 100	percent	n.a.	82	
	All plants	kkg	Feathers	16.9	
			Offal	200	
Dairy Products					
Receiving	Cans bulk	(kkg milk) equiv. received	BOD_5	0.5	292
Raw milk				0.3	
Fluid products				1.5	
Butter				0.8	
Natural cheese				0.7	
Cottage cheese				8.0	
Ice cream				3.0	
Condensed milk				1.0	
Dry milk				1.5	

TABLE VI-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201,202

a. LWK = Live weight killed.

b. Simple slaughterhouses have few by-product processing operations.[290]

c. Complex slaughterhouses have many by-product operations.[290]

d. Processing involves both freshly slaughtered and processed meats for curing, canning, freezing, cooking, and other meat products preparation. A low-processing meat-packing plant produces some processed meat, but less than or equal in weight to the amount freshly killed.[290]

e. High processing meat-packing plants slaughter and process animals and may also process meat from animals slaughtered elsewhere.[290]

f. Calculated assuming ratio of 0.5 kg SS per kg BOD_5 found in red-meat processing plants and also in poultry processing plants.

g. Calculated assuming this pollutant is discharged at a rate similar to that found in complex red-meat slaughterhouses.

In poultry processing plants 1,000 kg of live birds will generate about 7.0 kg BOD_5 and 7,500 l of wastewater.[258] This estimate assumes that good treatment plant technology prevails in 1974. The SS load is approximately half that of BOD_5 in poultry processing.[91] Due to the similarity in wastewater pollutants for both poultry processing and slaughterhouses, the pollutant output is assumed to be 7.0 kg BOD_5 per kkg killed and 3.5 kg SS per kkg killed. Other wastewater pollutants are approximately the same as for a complex slaughterhouse.[258] The confidence level of the discharge factors estimated in this section is 3, indicating a ± 25 percent possible variation in the data.

Industry Description and Schematic.

Figures VI-1 and VI-2 illustrate the basic production steps in the Meat and Dairy Products Industry. The major steps are common to all animal (including poultry) processing plants. The major pollutant manufacturing activities are killing: hair, feather, and hide removal; eviscerating; and cutting. The cut meat may undergo further processing steps which contribute additional pollutants, but these are not major wastewater pollution discharge sources. Dairy products are almost always filtered and pasteurized. Additional processing steps vary, depending on the nature of the dairy product being produced.

Economic Forecasts.

Red Meat Products. The demand for meat in the U.S. has shown a steady upward trend since the early 1960's. Domestic meat production has also increased, rising from 12.8 billion kg in 1960 (or 70.8 kg per capita) to an estimated 16.7 billion kg (or 80.3 kg per capita) in 1972.[182] Annual per-capita consumption of meat was estimated at about 84.4 kg in 1972;[182] thus, about 4 kg per capita of net meat imports were required to supplement domestic consumption. Meat imports were mainly composed of beef and veal from Australia. The increase in meat consumption has resulted almost entirely from a marked increase in the demand for beef. Beef demand has increased rapidly both in absolute volume and in per-capita consumption. In contrast, other meat items show either a stagnant or declining trend. Pork production has increased slightly since 1960, rising from 5.3 billion kg in 1960 to 6.1 billion kg in 1970; on an annual per-capita basis, pork consumption peaked in 1971 at 33 kg and declined to about 31 kg in 1972. Total production of lamb and mutton has declined in absolute terms from 0.34 billion kg in 1960 to 0.29 billion kg in 1970. Annual per-capita consumption of lamb and mutton has trended downward steadily from about 1.9 kg in 1960 to 1.2 kg in 1970, and has since stabilized. Although beef and veal are classified as a single class of meat in this study, it is important to note that the per-capita use of veal has declined dramatically in the 1960-1970 period from 2.8 kg to 1.3 kg per capita annually. Veal consumption has continued to decline since 1970, with annual per-capita consumption estimated at 1.2 kg in 1971. These reductions may be explained by the high price of veal, so that as the demand for beef has advanced, the production of veal has declined. Hence, calves are increasingly moved to feedlots for fattening and eventual slaughter as beef.[139] Recent trends in production and consumption of different classes of meat are summarized in Table VI-3.

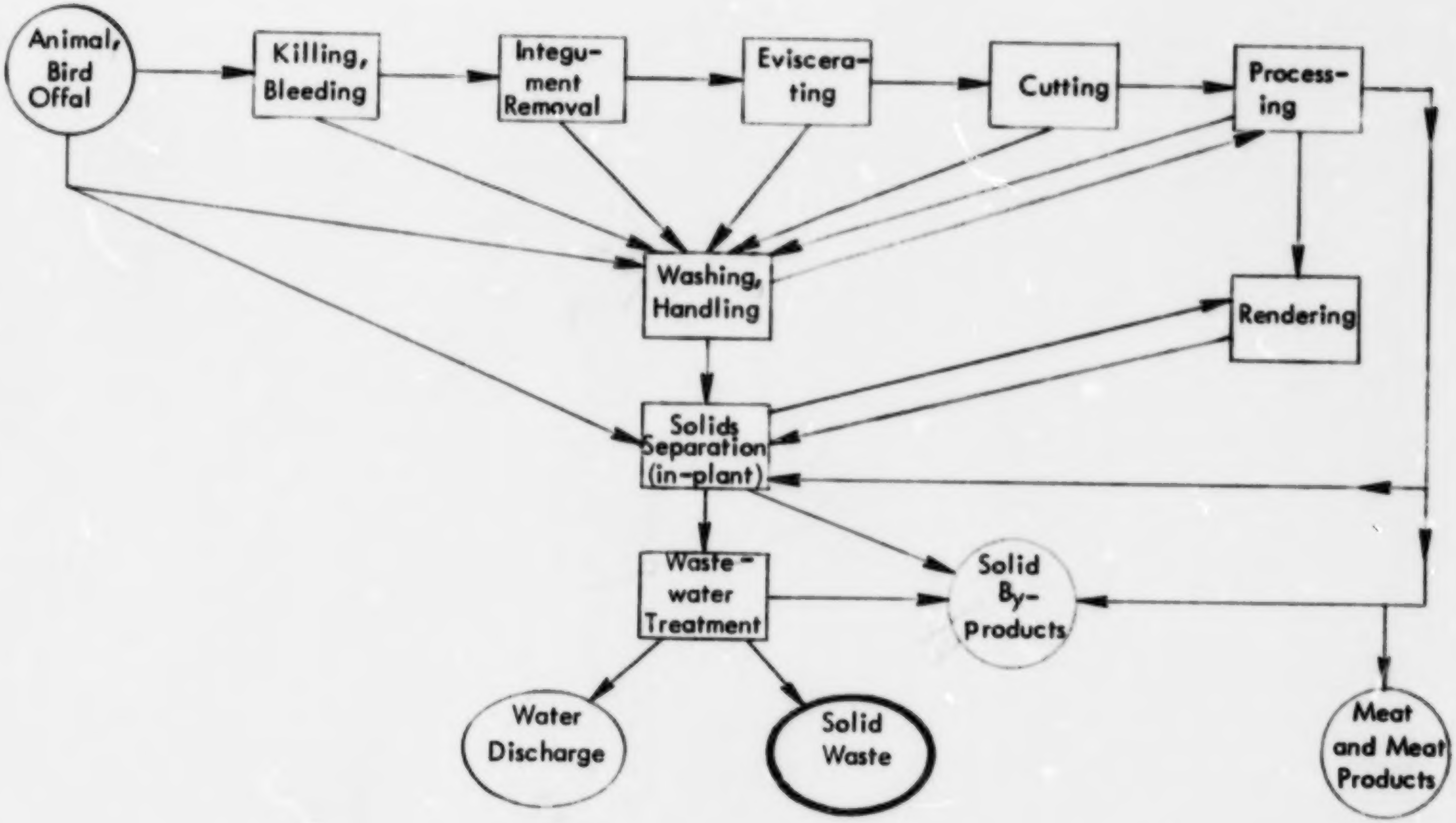
Animal, Bird Offal
Killing, Bleeding
Integu- ment Removal
Eviscera- ting
Cutting
Process- ing
Washing, Handling
Rendering
Solids Separation (in-plant)
Waste- water Treatment
Solid By- Products
Water Discharge
Solid Waste
Meat and Meat Products

FIGURE VI-1
INDUSTRY SCHEMATIC:
MEAT PRODUCTS

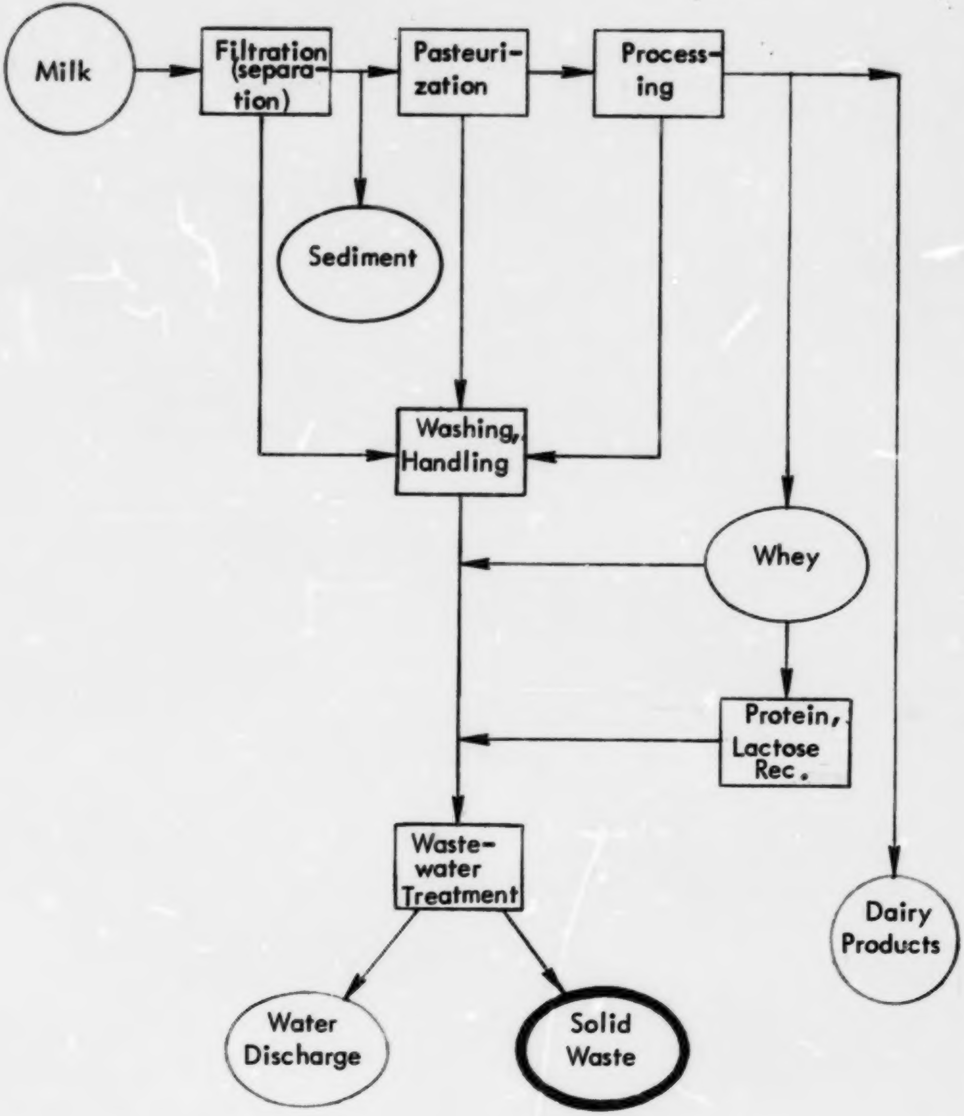
Milk
Filtration (separation)
Pasteurization
Processing
Sediment
Washing, Handling
Whey
Protein, Lactose Rec.
Wastewater Treatment
Dairy Products
Water Discharge
Solid Waste

FIGURE VI - 2
INDUSTRY SCHEMATIC:
DAIRY PRODUCTS

TABLE VI-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 201,202

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Dairy Products:										
Milk	Production	milk equivalent index	1972	102	100				334	1973
			1973	101						
	Average yield/ per cow/yr	10^3 kg	1972	4.8					292	1973
	Consumption	kg/capita	1969	219			244		329	1972
			1972	249				227	333	1973
Receiving	Raw milk	10^6 kg	1970	51,000					292	1973
Fluid products	Milk equivalent	% of milk used as		45.1						
Butter				22.2						
Natural cheese				17.0						
Cottage cheese				1.0						
Ice cream				11.4						
Condensed and dry milk				3.3						
Meat and Poultry Products:										
Beef	Total production	10^9 kg	1972	10.3					327	1972
			1973	10.7			12.2		327	1972
							13.1		181	1972
			1970	9.8				14.2	139	1973

TABLE VI-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 201,202

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Beef (cont.)	Consumption	kg/capita	1960	70.8					139	1973
			1971	84.4						
			1972	80.3						
			1985	105.7						
Pork	Total production	10^9 kg	1970	6.2					325	1973
			1972	9.1						
			2000	9.5						
	Consumption	kg/capita	1969	29.5			30.1		329	1972
			1972	30.6	33.1				330	1973
			1973	31.3					330	1973
Lamb and mutton	Total production	10^6 kg	1970	250					325	1973
			2000	272						
		index	1972	100					326	1973
			2000	100						
	Consumption	kg/capita	1970	1.5					325	1973
			2000	1.4						
All chickens	Consumption	kg/capita	1970	18.6				22.7	139	1973
					18.6			23.6	184	1973
							20.4		329	1972
Broilers	Consumption	kg/capita	1969	17.7			20.3		329	1972
			1972	17.6	16.8			21.8	184	1973

TABLE VI-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 201,202

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Poultry	Further processed	kg/capita			2.9			4.5	138	1972
Eggs	Consumption	eggs/capita	1972 1973	307 296					332	1973
	Production	10^9 eggs	1970	70	71.6					1972
Turkeys	Consumption	kg/capita			3.9			4.8	184	1973

Several factors account for the trends in meat demand depicted in Table VI-3. Among these are:

(1) Changes in consumer preferences from non-meat food items and lower-quality meats to some higher-cost meat products, particularly beef.

(2) Increase in disposable income per person has provided the purchasing power to enable greater meat consumption.

(3) Increased United States population has generated an increase in total demand for meat.[139]

(4) Higher costs of certain meat products have caused consumer shifts.

(5) Prepackaged foods and restaurant meals generally favor beef products.

The forecasts on meat production are predicated on several assumptions, including the following:

(1) The recent shortages, boycotts, and other disturbances experienced in the meat industry constitute short-run phenomena that should be resolved upon a return to free-market conditions following termination of National Phase IV economic controls.

(2) Future economic and population conditions will for the most part reflect current trends. Population increases through 1985 were assumed to be in line with the U.S. Census Bureau's Series "E" projection of an annual growth rate of slightly less than 1.00 percent. Total employment is expected to rise at about 1.5 percent per year and gross National product and labor productivity are projected to increase annually by 4 percent and 3 percent, respectively.[139]

Given these basic assumptions about economic and demographic conditions in the U.S., the demand for meat products in 1985 has been forecast by the Economic Research Service of the U.S. Department of Agriculture. These projections, shown in Table VI-3, have been selected for use in this study because the underlying assumptions, some of which are mentioned above, appear to be sound. Projections based on interpolation between current levels of consumption and 1985 projections have been established for the years 1975 and 1980 for the three major meat classifications.

Meat consumption is projected to reach 22.8 billion kg per annum by 1985, an increase of 28 percent over current levels. This increase will be accounted for primarily by the higher beef consumption projected to reach 15.0 billion kg by 1985, 0.9 billion kg of which will come from imports. Pork, lamb and mutton are all predicted to show only slight increases in absolute amounts, with per-capita levels of consumption staying constant through 1985.

Poultry Products. The demand for poultry meat in the U.S. has been increasing steadily during the past decade. Annual per-capita consumption rose from 15.5 kg in 1960 to 22.5 kg in 1970; further gains have occurred since 1970, with per-capita consumption of chicken and turkey estimated at 22.6 kg and 23.6 kg in 1971 and 1972 respectively.[184]

This growth in poultry meat demands is attributable to advances in production, processing, and marketing techniques which, until the recent market turbulence, succeeded in bringing lower poultry prices relative to other animal products and wider market outlets.[139] In addition, poultry demand was boosted by the massive growth in the processed convenience foods area, since chicken and turkey together account for 50 percent to 75 percent of such items as frozen dinners, meat pies, roasts, and other items in the processed line.[138]

Demand for poultry is projected to increase strongly through 1985, although not as rapidly as during the last decade. Assuming continued improvement in general economic conditions, a moderate rate of population increase (1% per annum), and further gains in production and marketing efficiency, the Economic Research Service of the U.S. Department of Agriculture has forecast that per-capita consumption of poultry meat will reach about 27.2 kg in 1985. Total consumption in 1985 should reach 6,476 million kg.[139]

Dairy Products. The dairy market has weakened steadily over the past 20 years. Consumption per capita has plunged as butter, cream, and other high-fat dairy products have met strong price competition from vegetable substitutes. In addition, consumer preferences have shifted away from dairy products as the industry has been subjected to criticism concerning diet and health effects.[139]

Recent and projected trends for the dairy industry are summarized in Table VI-3. It is projected that per-capita consumption (milk equivalent of all uses) of all dairy products may fall to about 227 kg annually per person by 1985. Such a reduction would probably offset the effect of population growth, leaving total dairy production at about 53,000 million kg, a level little higher than current output.[139] Projected levels for 1975 and 1980 have been estimated using methods of interpolation from the 1985 forecast. The confidence level of all economic forecasts presented in Table VI-3 is 3, indicating a ± 25 percent possible variation in the data.

Comprehensive Forecasts of Growth through 1985. Table VI-4 is derived from the data in Table VI-3 . Where the data in Table VI-3 did not include each of the four forecast years used in this study (1971, 1975, 1980, and 1985), the data were obtained by interpolation and extrapolation; these projections were simplified by employing linear rather than exponential interpolations and extrapolations. The methods used in forecasting each individual item are explained in the footnotes to the table.

TABLE VI-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 201,202

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Milk Products:										
Fluid	Milk equivalents	% of Total milk	45.1	292	45.1	9	45.1	a	45.1	a
Butter			22.2		19.5		16.7		14.3	
Natural cheese			17.0		19.0		21.0		23.0	
Cottage cheese			1.0		1.1		1.2		1.3	
Ice cream			11.4		12.0		12.8		13.2	
Condensed and dry milk			3.3		3.3		3.2		3.1	
Total			100.0		100.0		100.0		100.0	
Fluid	Milk equivalents	10^6 kg	24,113	d	24,122	d	24,133	d	24,140	d
Butter			11,870		10,430		8,936		7,654	
Natural cheese			9,089		10,162		11,237		12,311	
Cottage cheese			535		589		642		696	
Ice cream			6,095		6,418		6,850		7,065	
Condensed and dry milk			1,764		1,765		1,712		1,659	
Total		10^6 kg	53,466		53,486		53,510		53,525	

TABLE VI-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 201,202

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Milk products: (cont.)										
U.S. population		millions	207	136	214	136	224	136	236	136
Milk production	Milk equivalent	kg/capita/yr	259	c	250	c	238	c	227	c
Meat products:										
Beef and veal	Processed wt.	10^9kg	10.6	330	11.6	f	12.9	f	15.0	139
	LWK		17.7	f	19.4	f	21.6	f	25.0	f
	Processed wt.	kg/capita	51.2	330	54.4	e	57.6	e	63.5	139
	LWK		85.3	e	90.7	e	96.2	e	105.7	e
Pork	Processed wt.	10^9 kg	6.8	330	7.0	f	7.3	f	7.5	139
	LWK		10.2	f	10.4	f	10.8	f	11.2	f
	Processed wt.	kg/capita	33.1	330	32.7	g	32.2	g	31.8	139
	LWK		49.4	g	48.5	g	48.1	g	47.2	g
Lamb and mutton	Processed wt.	10^9 kg	0.3	330	0.3	f	0.3	f	0.3	139
	LWK		0.6	f	0.6	f	0.6	f	0.6	f
	Processed wt.	kg/capita	1.4	330	1.4	h	1.4	h	1.4	139
	LWK		2.7	h	2.7	h	2.7	h	2.7	h

TABLE VI-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 201,202

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Total red meat	Processed wt.	10^9 kg	17.7		18.9		20.5		22.8	
	LWK		28.5		30.4		33.0		36.8	
	Processed wt.	kg/capita	85.7	c	88.5	c	91.2	c	96.6	c
	LWK		137.4	c	142.0	c	147.0	c	155.6	c
Poultry Products:										
Chicken	Processed wt.	10^9 kg	3.9	184	4.3	f	4.8	f	3.4	139
	LWK		4.9	f	5.4	f	6.0	f	6.8	f
	Processed wt.	kg/capita	18.8	184	19.8	i	21.2	i	22.7	139
	LWK		23.7	i	25.0	i	26.8	i	28.6	i
Turkey meat	Processed wt.	10^9 kg	0.8	184	0.9		1.0		1.1	184
	LWK		1.0	i	1.1	i	1.3	i	1.4	i
	Processed wt.	kg/capita	3.9	184	4.1	i	4.4	i	4.8	184
	LWK		4.9	i	5.2	i	5.6	i	6.0	i
Total	Processed wt.	10^9kg	4.7		5.1		5.8		6.5	
	LWK		5.9		6.5		7.3		8.2	

TABLE VI-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 201,202

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Total poultry	(cont.)									
	Processed wt.	kg/capita	22.6		23.9		25.6		27.4	
	LWK		28.6		30.2		32.4		34.7	
Further processed poultry	Processed wt.	10^9	0.6	f	0.8	f	1.0	f	1.3	f
		kg/capita	2.9	138	3.6	k	4.5	138	5.4	k
Eggs	Consumption	10^9 eggs	71.6	27	71.6	l	71.6	l	71.6	l

TABLE VI-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 201,202

[a] Fluid products have remained a fairly constant percentage of total milk production. Total butter production has been declining at approximately 3 percent per year, cheese has been increasing at over 3 percent per year, and ice cream has been increasing at less than 2 percent per year.[292] These trends were incorporated into the forecasts of the percentage breakdown of milk products using linear extrapolation.

[b] Linear interpolation between 249 kg/capita/year in 1972 and 227 kg/capita/year in 1985.[333]

[c] Derived from production total figure above and forecast of population growth (see sample derivation of population figures in Section XVII).

[d] Percentage forecast from (a) above multiplied by total milk production figure from (c).

[e] Interpolated 1975 and 1980 from 1971 and 1985 figures. Processes weight equals 60 percent of live weight.

[f] Per capita figures multiplied by population growth.

[g] Interpolated 1975 and 1980 from 1971 and 1985 figures. Processed weight equals 67 percent of live weight.

[h] Constant per capita consumption through 1985. Processed weight equals 52 percent of live weight.

[i] 1975 and 1980 interpolated from 1971 and 1985 data from Table VI-3. Processed weight equals 79 percent of live weight.

[j] 1975 by linear interpolation between 1971 and 1980, 1985 by linear extrapolation of 1971 to 1980 trend.

[k] Per capita egg consumption decreases have offset population increases in recent years.

Discharge Inventory of Pollutants Capable of Producing Solid Wastes.

Table VI-5 notes the discharge inventories for BOD_5 and suspended solids, the two major water pollutants capable of producing treatment plant solid wastes residues. The table was developed assuming old technologies before treatment. The Table VI-2 discharge rate figures were multiplied by the corresponding Table VI-4 forecasts to obtain the estimated wastewater pollution discharges. The meat discharges were then increased 44 percent and the poultry discharge 18 percent to account for primary in-plant treatment. The red meat discharges were calculated assuming the discharge factors for "complex slaughterhouses." These slaughterhouses do some meat processing and their discharge factors were between simple slaughterhouses and high-level packinghouses. Total meat and dairy discharges of BOD_5 were forecast to increase from 703.2 million kg in 1971 to 886.8 million kg in 1985. Suspended solids discharges are forecast to increase from 554.1 million kg in 1971 to 709.4 million kg in 1985.

Because of the compounding inaccuracies in the economic forecasts and the water pollution discharge factors, the confidence level for the discharge inventory of pollutants is 2, indicating a ± 50 percent possible variation in the data.

Likely Pollution Treatment Processes.

Table VI-6 presents alternative treatment processes available for pollutant discharges from the Meat and Dairy Products Industry. Figure VI-3 represents these alternatives in schematic form. In dairy plants, the general heading "In-Plant Controls" is listed for various types of dairy products. These controls include mainly preventative measures to reduce or eliminate sources of spillage. For this reason their impact on solid wastes is minimal and they have been given a value of zero in Table VI-6. These methods break down into two general areas:[292]

1. Improving management of plant water usage and reduction in waste materials.

2. Engineering improvements to plant, equipment, processes, and ancillary systems.

Plant management improvement includes better scheduling to reduce start-up and shut-down losses, education to reduce spillage, waste monitoring, better plant maintenance, and alternate reclamation of waste materials as by-products.

Engineering improvements entail physical modifications of existing plant equipment to reduce sources of loss and the use of newer, more efficient manufacturing processes. Such improvements seldom produce large amounts of solid wastes.

Primary in-plant controls, mainly consisting of physical or mechanical removal methods such as screening, are in Table VI-6 for red meat and poultry plants. These methods create dry residues approximately equal to the suspended solids removed. Advanced "end of pipe" waste water treatments are also shown for all sectors in meat and dairy plants. Lagooning of meat and dairy wastes creates practically no solid residues because

TABLE VI-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Pollutant: Item	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
BOD$_5$:						
Milk Products						
Receiving[b]		292	21.4	21.4	21.4	21.4
Fluid products			36.2	36.2	36.2	36.2
Butter			9.5	8.3	7.1	6.1
Natural cheese			6.4	7.1	7.9	8.6
Cottage cheese			4.3	4.7	5.1	5.6
Ice cream			18.3	19.2	20.6	21.2
Condensed and dry milk			2.2	2.2	2.1	2.1
Total			98.3	99.1	100.4	101.2
Meat and Poultry Products						
Beef and veal	Complex slaughterhouse	290	345	378	420	486
Pork	Complex slaughterhouse	290	198	202	211	218
Lamb and mutton	Complex slaughterhouse	290	11.6	11.6	11.6	11.6

TABLE VI-5(Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Pollutant Item:	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Total meat			554.6	591.6	642.6	715.6
Chickens	LWK	7	[illegible].8	46.1	51.2	58.0
Turkeys			8.5	9.4	11.1	12.0
Egg production		a	--	--	--	--
Total poultry			50.3	55.5	62.3	70.0
Total Milk, Meat, and Poultry			703.2	746.2	805.3	886.8
Suspended Solids:						
Milk Products						
Receiving		40% of BOD_5	8.6	8.6	8.6	8.6
Liquid production			14.5	14.5	14.5	14.5
Butter			3.8	3.3	2.8	2.4
Natural cheese			2.6	2.8	3.2	3.4
Cottage cheese			1.7	1.9	2.0	2.2
Ice cream			7.3	7.7	8.2	8.5
Condensed and dry milk			0.9	0.9	0.8	0.8
Total			39.4	39.7	40.1	40.4

TABLE VI-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Suspended Solids:						
Meat and Poultry Products						
Beef and veal	Complex slaughterhouse	290	304	334	370	429
Pork	Complex slaughterhouse	290	175	177	186	191
Lamb and mutton	Complex slaughterhouse	290	10.4	10.4	10.4	10.4
Total meat			489.4	521.4	566.4	630.4
Chickens		7	21.0	23.0	25.6	29.0
Turkeys		7	4.3	4.6	5.6	9.6
Eggs		a	--	--	--	--
Total poultry			25.3	27.6	31.2	38.6
Total Milk, Meat, and Poultry			554.1	588.7	637.7	709.4

TABLE VI-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 201, 202

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Phosphorous, Chlorides, and Dissolved Pollutants:						
Meat and Poultry	Total	0.5 x SS	257	274	299	334

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[a] Contribution of egg production to total water pollution from poultry sector is very minor; no specific data were available.

[b] Average figure for canned and bulk receiving discharges used.

TABLE VI-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 201, 202

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: \$ per Physical Unit	Ref. No.
AIR POLLUTANTS							
Meat smoking		Particulates	Wet collector and low voltage precipitator	67	1		169
			Direct fire after-burner	67	0		
WATER POLLUTANTS							
Milk Products							292
Receiving	Can	BOD_5	In-plant controls	20	0		
	Bulk			33	0		
	Can	SS		20	0		
	Bulk			33	0		
Fluid products		BOD_5		66.7	0		
		SS		66.7	0		
Butter		BOD_5		62	0		
		SS		62	0		
Natural cheese		BOD_5		72	0		
		SS		72	0		

TABLE VI-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 201, 202

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Milk Products (Cont.)							292
Cottage cheese		BOD5	In-plant controls	41	0		
		SS		41	0		
Ice cream		BOD_5		63	0		
		SS		63	0		
Condensed, dry milk		BOD_5		50	0		
		SS		50	0		
All milk products		BOD_5	Biological-1977	90	0.1		
			Biological-1983	96	0.1		
			Sand filtration	60	<1.0		
			Irrigation	100	0.0		
Meat Products		BOD_5	Primary in-plant physical removal	44	n.a.[a]		258
		SS		44	1		
Poultry Products		BOD_5	Primary in-plant physical removal	18	n.a.		
		SS		18	1		

TABLE VI-6(Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 201, 202

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Meat and Poultry		Grease	Dissolved air flotation (DAF)	60	1		290
		SS		30	1		
		BOD_5		30	1		
		Grease	DAF + inorganic coagulants	95-99	1.2 kg/kg SS		
		SS		90			
		BOD_5		98			
		P		85-95			
		BOD_5	Anaerobic lagoon & extended aeration	99	n.d.[b]		258 290
		BOD	Anaerobic contact & aerobic lagoon	95.4	0.1		290
		SS		93.5			
		Grease		95.3			
		BOD	Anaerobic contact & aeration & aerobic lagoon	98.3	0.6		290
		SS		93.3			
		Grease		98.5			

TABLE VI-6(Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 201, 202

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: \$ per Physical Unit	Ref. No.
Meat and Poultry (Cont.)							290
		BOD_5	Activated sludge	90-95	n.d.		
		BOD, SS Grease, P,N	Spray/flood irrigation	100	0		
		BOD_5	Activated carbon	98	n.d.		
		BOD_5 SS	Sand filter	100 100	1		
		BOD_5 SS	Microstrainer	100 100	1		
		P	Chemical precipitation	85-95	>1		
		Dissolved pollutants	Ion exchange	98	1		

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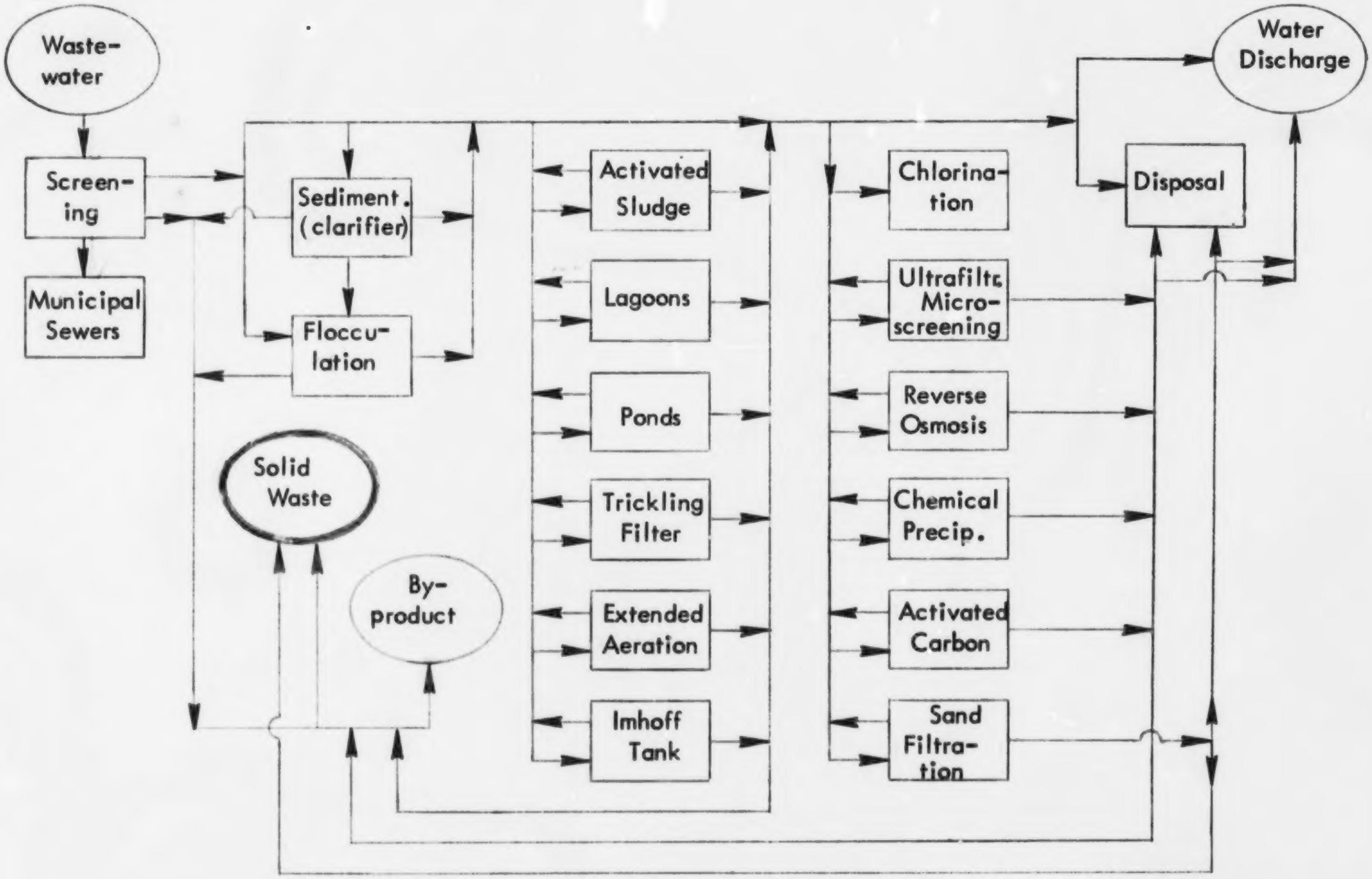
[a] n.a. = Not applicable.

[b] n.d. = No data available.



Waste-water
Screen-ing
Municipal Sewers
Sediment. (clarifier)
Floccu-lation
Solid Waste
By-product
Activated Sludge
Lagoons
Ponds
Trickling Filter
Extended Aeration
Imhoff Tank
Chlorina-tion
Ultrafiltr. Micro-screening
Reverse Osmosis
Chemical Precip.
Activated Carbon
Sand Filtra-tion
Disposal
Water Discharge

FIGURE VI - 3
WATER TREATMENT PROCESS SCHEMATIC:
MEAT AND DAIRY PRODUCTS

See below

of the high bio-degradable organic content of the residues. Biological treatments of milk wastes, including lagoons, trickling filters, etc., yield solid residues which average only ten percent of the dry weight solids removed. Aerobic lagooning followed by trickling filtration for red meat and poultry wastes creates approximately 0.6 kg of residues per kg solids removed. Only 40 to 50 percent of suspended solids are removed in the lagoon; the remaining suspended solids in the effluent are then treated by a trickling filter which then removes 10 percent more solids. Dissolved air flotation plus inorganic coagulation creates slightly more sludge solids than settling and skimming of the wastewater stream. This is created by the precipitation of iron sulfates, lime and polyelectrolytes. The calculation is shown as a footnote to the table.

Some processing plants use their cooling water blowdown for irrigation. This eliminates solid wastes while meeting discharge standards. Sand filters may be used to treat the effluent from lagoons and from secondary biological treatment plants. The sludge residues created will be a proportion slightly greater than one to the solids in the effluent reaching the sand filter. The exact figure will be a function of the amount of filter waste material and the type of backwashing employed. The calculations in this section assume a diatomite filter wastage equal to 10 percent of the industrial waste solids removed. The confidence level for the data in this section is 4, indicating a ± 10 percent possible variation in the data.

Reuse Potentials for Solid Waste Residues Produced by Pollution Treatment Processes.

The degree of reuse of solid waste residues is a function of the source of the waste and the treatment method employed. Reverse osmosis of cottage cheese whey waste streams yields lactose and protein. Biological treatment of these same wastes decomposes them and creates non-reusable residues. See Table VI-7 for reuse estimates.

Primary physical removal systems in meat and poultry plants yield paunch material, skin, feathers, and offal which can be reclaimed after rendering and drying as by-products, mainly as animal protein food supplements. The residues from more advanced biological methods are usually not reused.

The grease recovered in dissolved air flotation can similarly be reclaimed as a by-product. The average proportion of grease to suspended solids (derived from Table VI-2) is approximately 61 percent for complete slaughterhouse wastewaters and varies around this level for other types of plants. Simple dissolved air flotation removes grease more efficiently than normal suspended solids, however, so that the reuse estimate is 80 percent. Dissolved air flotation plus inorganic coagulation achieves high efficiencies for both suspended solids and grease removal. A 61 percent reclamation percentage is estimated for this material. The confidence level for data in this section is 2, indicating a ± 50 percent possible variation in the data.

TABLE VI-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 201, 202

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Description/Disposal of Residue
Dairy				
Cottage cheese		Ultrafiltration plus reverse osmosis of whey	100	Lactose and protein
Plant wastewater		Biological	0	Highly organic
Meat and Poultry		DAF	80	Grease
		DAF plus inorganic coagulants	61	Grease
		All other biological methods	0	Landfill or soil amendment material
		In-plant primary removal systems	95	Blood, offal, paunch material for meat scrap production, feathers to feather meal.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables VI-8 to VI-11 synthesize the information contained in previous tables and permit final estimates of the impact of air and water pollution control on solid waste residues.

Although the control of air pollution from meat smoking and some other minor operations creates some residues, no data were available with which to make a quantitative estimate.

The estimates of which treatments will be used for water pollution control in the future and those used in 1971 are rough approximations. Primary in-plant treatments were assumed to remove 18 percent of poultry wastes and 44 percent of red-meat wastes. The remaining pollutants in the effluent are treated by more advanced methods. Dissolved air flotation (DAF) is a common treatment, and was assumed to comprise a large and increasing percentage of plant end-of-pipe pre-treatment in the future. Inorganic coagulation combined with dissolved air flotation is very effective and is forecast to play an increasing role in future wastewater pollution control. Biological controls will also be significant in the future.

Spray irrigation is used where plants are near suitable agricultural land, and is not forecast to play a predominant role in coming years. Lagooning of wastes from this industry generates no significant solid wastes. Some solid wastes are generated when lagoons are followed by trickling filters. Two types of treatment processes, plain lagoons (with aerators) and lagoons followed by trickling filters, are the likely secondary treatment methods for meat and poultry products.

Since some of the wastewater treatment processes are employed sequentially, a calculation of the percent of the original suspended solids before treatment remaining in the effluent for further treatment is given at the end of each step in Tables VI-8 through VI-11. The percent treated by each process is that of total pollutants discharged before treatment.

Tables VI-8 through VI-11 estimate that the total solid residues from water pollution control in the Meat and Dairy Products Industry will more than double by 1985, from 65×10^6 kg in 1971 to 220×10^6 in 1985. Of this total, the majority of the solid waste contribution will be from the meat and poultry sectors; these should account for 85.6 percent of the solid wastes generated in 1971, 89.0 percent in 1975, 94.2 percent in 1980, and 97.9 percent in 1985. This relative increase in the contribution of the meat and poultry solid wastes from water pollution control is due mainly to the fact that while contributions from these sectors are expected to rise from 35×10^6 kg in 1971 to 208×10^6 kg in 1985 (a 41 percent increase), contributions from the milk products sector are expected to decline from 15.6×10^6 kg in 1971 to 6.1×10^6 kg in 1985 (a 39 percent decrease). Contributions of air pollution control to solid waste residues will be minimal for the Meat and Dairy Industry Products.

The data in this final forecasts section may be given a confidence level of 2, indicating a possible 50 percent variation in the data.

TABLE VI-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Meat	Smoking	Wet collector to precipitator	n.d.		67		100	n.d.
		Afterburner	n.d.		67		100	n.d.
Total Residues from Air Pollution Control:								n.d.[a]
WATER POLLUTANTS								
SS and Flotable Solids:								
Milk products		In-plant controls	0					
Poultry products		In-plant controls	18	5	100	5	5	negl
Meat products		In-plant controls	44	220	100	220	5	10
[Meat and poultry: SS remaining in effluent = 57% = 293.4 x 10^6 kg]								
Milk products		Biological - 1977	50	20	90	20	100	20
		- 1983	0		96		100	
[Milk: SS remaining in effluent = 55% = 22 x 10^6 kg]								
Meat and poultry		Secondary						
		DAF	40	120	30	40	20	7
		DAF & inorganic coagulants	15	50	90	40	39	20
		Anaerobic contact and aerobic lagoon	5	2	99	2	100	2

TABLE VI-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC: 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Meat and poultry (cont.)		Anaerobic lagoon and trickling filter	10	6	94	6	100	6
		Activated sludge	0	0	85	0	0	0
		Spray/flood irrigation	10	0	100	0	0	0
		None	20	0				
[SS for meat and poultry requiring further treatment: 26% = 147.1 x 10^6kg]								
Phos., chlorides, & dissolved pollutants:								
Meat, poultry, and milk		Ion exchange	0	0				
Total Residues from Water Pollution Control:				420	79	333	20	65

[a] No data concerning discharges of particulates from meat smoking were available, and thus no estimate of residues from particulate treatments was given in Tables VI-8 through VI-11. Residues from air pollution control, however, can be expected to be relatively insignificant compared to residues generated from water pollution control in the Meat and Dairy Products Industry.

TABLE VI-9
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Meat	Smoking	Wet collector & precipitator	50	n.d.	67		100	n.d.
		Afterburner	50	n.d.	67		100	n.d.
Total Residues from Air Pollution Control:								n.d.[a]
WATER POLLUTANTS								
SS and Flotable Solids:								
Milk products		In-plant controls	0	0			0	0
Poultry products		In-plant controls	18	5.0	100	5	5	5
Meat products		In-plant controls	44	230	100	230	5	10
				[Meat and poultry: SS remaining in effluent = 57% = 315 x 10^6 kg]				
				[Milk: SS remaining in effluent = 100% = 42.6 x 10^6 kg]				
Milk products		Biological - 1977	90	4	90	4	100	4
		- 1983	0					
				[Milk: SS remaining in effluent = 19% = 7.5 x 10^6 kg]				
Meat and poultry		DAF	40	130	30	40	20	8
		DAF & inorganic coagulants	15	60	90	50	39	20

TABLE VI-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 201,202

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Meat and poultry (cont.)		Anaerobic lagoon & aerobic lagoon	5	2	99	2	100	2
		Anaerobic lagoon & trickling filter	10	6	94	6	100	6
		Activated sludge	0	0	85	0	n.d.	0
		Spray/flood irrigation	15	0	100	0	0	0
		None	15	0				
				[SS for meat and poultry requiring further treatment: 31% = 174 x 10^6 kg]				
Phos., Chlorides, & Dissolved Pollutants:								
Meat, poultry, and milk		Ion exchange	20	50	98	50	100	50
Total Residues from Water Pollution Control:				490	80	390	26	100

TABLE VI-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 201, 202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Meat	Smoking	Wet collector & precipitator		n.d.	67		100	n.d.
		Afterburner		n.d.	67		100	n.d.
Total Residues from Air Pollution Control:								n.d.[a]
WATER POLLUTANTS								
SS and Flotable Solids:								
Milk products		In-plant controls	20	0	100	0	0	0
Poultry products		In-plant controls	18	6	100	6	5	negl.
Meat products		In-plant controls	44	250	100	250	5	10
			[Meat and poultry: SS remaining in effluent = 57% = 341 x 10^6 kg] [Milk: SS remaining in effluent = 80% = 32 x 10^6 kg]					
Milk products		Biological-1977	50	2	90	2	100	2
		-1983	40	2	96	2	100	2
			[SS remaining in effluent = 13.3%]					
Meat and poultry		DAF	42	140	30	40	20	9
		DAF & inorganic coagulants	20	80	90	70	39	30
		Anaerobic contact & aerobic lagoon	12	4	99	4	100	4

TABLE VI-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Meat and poultry (Cont.)		Anaerobic lagoon & trickling filter	5	3	94	3	100	3
		Activated sludge	0	0	85	0	n.d.	0
		Spray/flood irrigation	13	0	100	0	0	0
		None	8	0				
[SS for meat, milk, and poultry requiring further treatment: 23%=136 x 10^6kg]								
Phos., Chlorides, & Dissolved Pollutants:								
Meat, poultry, and milk		Ion exchange	25	80	98	80	100	80
Total Residue from Water Pollution Control:				570	81	460	30	140

TABLE VI-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Meat	Smoking	Wet collector & precipitator	50	n.d.	67		100	n.d.
		Afterburner	50	n.d.	67		100	n.d.
Total Residues from Air Pollution Control:								n.d.
WATER POLLUTANTS								
SS and Flotable Solids:								
Milk products		In-plant controls	45	0			0	
Poultry products		In-plant controls	18	7	100	7	5	negl
Meat products		In-plant controls	44	280	100	280	5	10
[Meat and poultry: SS remaining in effluent=58% =385 x 10^6 kg]								
[Milk: SS remaining in effluent =55% =33 x 10^6 kg]								
Milk products		Biological-1977	20	1	90	1	100	1
		Biological-1983	70	2	96	2	100	2
[SS remaining in effluent 8 %]								
Meat and poultry		DAF	10	40	30	10	20	2
		DAF & inorganic coagulants	42	190	90	170	39	70
		Anaerobic lagoon & aerobic lagoon	19	7	99	7	100	7

TABLE VI-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 201,202

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Meat and poultry (Cont.)		Anaerobic lagoon & trickling filter	15	10	94	9	100	9
		Activated sludge	0	0	85	0	0	0
		Spray/flood irrigation	10	0	100	0	0	0
		None	4					
			[SS for meat, milk, and poultry requiring further treatment: 9% = 65 x 10^6 kg]					
Phos., Chlorides, & Dissolved Pollutants:								
Meat, poultry, and milk		Ion exchange	35	120	98	120	100	120
Total Residues from Water Pollution Control:				660	92	610	36	220

Factors Affecting the Quality of the Data.

The discharge factors for the Meat and Dairy Products Industry are fairly accurate, although they are industry averages which would not apply to any particular plant. Economic forecasts are subject to greater variation, especially in the light of recent fuel shortages and large market price fluctuations. The export future of these commodities remains uncertain. The confidence level for the economic forecasts is probably 3, indicating a ± 25 percent possible variation in the data.

The biggest source of error for the forecast in this industry is in the estimate of future wastewater plant treatment facilities. Different treatment methods with similar efficiencies vary greatly in their impact upon solid wastes. Thus the overall confidence level for this Section is established at 2, indicating a ± 50 percent possible variation in the data.

Summary.

Untreated Discharges. The majority of pollutants generated by the Meat and Dairy Products Industry are released to water. Meat smoking is a source of relatively insignificant amounts of particulates and hydrocarbons. The majority of the waste stream generated within these sectors is derived from the slaughtering and by-product handling steps. Untreated BOD_5 discharges were estimated to increase from 703 to 887 million kg between 1971 and 1985; total suspended solids discharges during the same period were forecast to increase from 554 to 709 million kg. Meat products account for the majority of these untreated BOD_5 and SS discharges. This sector, in addition, is forecast to generate significant amounts of untreated dissolved pollutants (e.g., phosphorus, chlorides); dissolved pollutant generation is forecast to increase from 257 to 334 million kg between 1971 and 1985.

Treatment Methods and Reuse. Primary in-plant controls (e.g., screening, settling) are common in the Meat Products Industry, and produce significant quantities of solid waste residues. Common wastewater treatment for meat and dairy product effluents are biological treatments, spray irrigation, ultrafiltration, reverse osmosis, dissolved air flotation, coagulation, lagooning, aeration, trickling filtration, and ion exchange. Ion exchange is used generally for dissolved pollutants only, while the remaining treatments are used for suspended solids and other flotables. From the latter advanced wastewater treatments, solid wastes are generated mostly from aerobic lagooning followed by trickling filtration, dissolved air flotation followed by inorganic coagulation, and ion exchange. The main instances of reuse in these industries are use of integument as food supplements for animals, and similar by-product reclamation of the grease produced from dissolved air flotation.

Residues Generated from Pollution Control: Types and Amounts. Total solid residues from water pollution control in these sectors are forecast to triple, from 65 to 220 million kilograms, between 1971 and 1985. The vast majority of the solid waste residues produced will likely be from meat products, which are also responsible for the majority of untreated discharges. The relatively insignificant contribution of the dairy products sector is expected to decrease by more than half, from 16 to 6 million kg, between 1971 to 1985. Most solid waste residues, by 1985, will be generated by dissolved air flotation followed by inorganic coagulation to control suspended solids and ion exchange to control dissolved solids in meat and poultry plant effluents.

SECTION VII
CANNED AND PRESERVED FRUITS AND VEGETABLES
SIC 203

Introduction.

The Canned and Preserved Fruits and Vegetables Industry is an important source of industrial water pollution in the United States. This industry includes canned, frozen, and dehydrated products, as well as chip products. The segments listed in the 1972 SIC Manual are:

SIC 2032	Canned Specialties
SIC 2033	Canned Fruits, Vegetables, Preserves, Jams and Jellies
SIC 2034	Dried and Dehydrated Fruits, Vegetables, and Soup Mixes
SIC 2037	Frozen Fruits, Fruit Juices, and Vegetables
SIC 2038	Frozen Specialties
SIC 2099	Potato and Corn Chips, segment of Miscellaneous Food Preparations Not Elsewhere Classified

In 1970 this industry accounted for 212 million kilograms of suspended solids and approximately 450 million kilograms of BOD_5, which represented nearly 4.5 percent of all industrial sources of BOD_5 and 2 percent of all suspended solids.[11] The industry also generates considerable quantities of solid wastes. Of approximately 8.5 million metric tons of solid food wastes generated annually by this industry, about 6.6 million are recycled. 1.5 million are spread, landfilled or burned; 0.3 million are disposed of in a water medium, and 1 million tons are not accounted for.[161] Another 0.6 million metric tons of non-food wastes are also generated by the industry, of which 0.2 million are recycled. An insignificant amount of non-food solid wastes is disposed to a liquid medium. One and one-half million metric tons of solid food residues and 0.4 million tons of solid non-food residues are incinerated each year.[161] Thus, a small contribution to total solid wastes would occur if the industry disposed to landfills the 0.2-0.3 million metric tons currently disposed to water. Because of the wide use of biological treatment methods and the highly organic content of food wastes, the future implementation of water pollution controls in the Canned and Preserved Fruits and Vegetables Industry will not produce large additional quantities of solid wastes.

Untreated Discharge Factors.

Air Pollutants. Air pollutant discharges are not a major problem in the Canned and Preserved Fruits and Vegetables Industry. The primary sources of air pollutants are the incineration of solid wastes and meat smoking. Data for these operations are presented in Table VII-1.

TABLE VII-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 203

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Industrial or commercial incineration	Multiple chamber	kkg burned	Particulates	3.5	169
			SO_2	0.75	
			Hydrocarbons	1.5	
			NO_2	1.5	
	Single chamber	kkg burned	Particulates	7.5	169
			SO_2	0.75	
			Hydrocarbons	7.5	
			NO_2	1.0	
	Controlled air	kkg burned	Particulates	0.7	169
			SO_2	0.75	
			Hydrocarbons	Negl.	
			NO_2	5	

[a] For 1971 or most recent available information.

Water Pollutants. Table VII-2 presents data for water pollutant discharges from fruit and vegetable processing operations. Composite BOD_5 and SS discharge factors for 10,000 No. 303 case equivalents are presented. Data comparing dehydrated and frozen potato products are presented to indicate the similarity of the waste streams. Because of a lack of detailed information for dehydrated products, they will be included with frozen products in the analysis of their impact upon solid wastes through air and water pollution control.

Because of the large number of steps in the manufacturing processes, and because of the large number of alternative equipment types which may be employed, a composite of particular techniques for all steps will be employed for this analysis. The methodology changes in the future will be included in the estimate of solid waste residues in Tables VII-11-14. These changes will include new manufacturing methods which reduce water pollutants. For example, dry peeling methods reduce suspended solids generation by approximately 65 percent over wet peeling methods. Most of this material becomes solid residues which will be incorporated in the solid waste estimates in Tables VII-11-14. The untreated discharge factors can be taken to have a confidence level of 2, indicating a ±50 percent possible variation in the data.

Industry Description and Schematic.

Figure VII-1 illustrates the basic steps involved in the freezing, canning, and dehydrating of canned and preserved fruits and vegetables which create pollutant streams. Most of the water pollutants are produced in the early steps; these steps are similar for different types of fruits and vegetables. Receiving, washing, peeling, pitting and coring create large quantities of suspended solids in almost every type of fruit and vegetable operation. Also, the transportation system wastes-flues and belt washing are common to most operations. Pasteurization, freezing and dehydration contribute smaller amounts of pollutants to the waste streams.

The reuse of process water is becoming increasingly common in the industry. Cooling water is often recycled for uses requiring lesser purity. Washing water may be reused after primary or sometimes secondary treatment. Treatment techniques for the wastes created are discussed in following sections.

Economic Forecasts.

Demand for processed fruits and vegetables has increased markedly over the last decade, and this trend will most likely continue. The available pollutant data are in terms of Standard No. 303 cases. It was necessary to make extrapolations of historical data in kilograms per-capita, and then convert these data to standard cases. These conversions are performed in Tables VII-3 and VII-4 and are further explained in the footnotes to these tables. Discussions of the individual products are presented below. The confidence level for this section is 3, indicating a ±25 percent possible variation in the data.

TABLE VII-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 203

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Canning[a]		10,000 #303 case equivalents			
Washing			BOD_5	848	92
			SS	1,163	
Belt conveyor			BOD_5	36	
			SS	78	
Sorting, pitting, slicing, etc.			BOD_5	163	
			SS	220	
Blanching/peeling			BOD_5	1,327	
			SS	1,297	
Exhausting of cans			BOD_5	36	
			SS	39	
Processing			BOD_5	158	
			SS	129	
Cooling of cans			BOD_5	156	
			SS	91	
Plant cleanup			BOD_5	366	
			SS	469	
Box washing			BOD_5	84	
			SS	142	
Total canning			BOD_5	3,175	
			SS	3,629	
Total canning range			BOD_5	1,179-4,763	
			SS	1,043-5,307	
Freezing[a]		10,000 #303 case equivalents			92
Wash sprays following mechanical harvesting			BOD_5	798	
			SS	1,134	
Belt conveyor			BOD_5	27	
			SS	50	

TABLE VII-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 203

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Freezing[a] (Cont.)		10,000 #303 case equivalents			92
Mech. sorting, trimming, pitting, etc.			BOD_5	148	
			SS	168	
Blanching			BOD_5	1,253	
			SS	1,070	
Plant cleanup			BOD_5	268	
			SS	299	
Total freezing			BOD_5	2,495	
			SS	2,722	
Total freezing range			BOD_5	1,021-3,946	
			SS	871-5,035	
Dehydrated potatoes	Dry peeling	kkg	BOD_5	14.4	162
			SS	11.1	
	Wet caustic peeling		BOD_5	27.4	
			SS	30.2	
	Steam peeling		BOD_5	22.3	
			SS	15.0	
Frozen potato products	Dry Peeling	kkg	BOD_5	19.6	162
			SS	13.6	
	Wet caustic peeling		BOD_5	32.6	
			SS	32.7	
	Steam peeling		BOD_5	27.6	
			SS	17.4	

TABLE VII-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER
POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 203

[a] These figures are derived from ranges cited in Ref. 92, pages 29 (for canned) and 82 (for frozen). The individual coefficients were calculated by using the industry average cited at the bottom of the table as a ratio to the sum of the upper and lower ranges. That is:

$$\text{Industrial Methodology Coefficient} = \frac{\text{Industry Total Average}}{\text{Industry Low} + \text{Industry High}} \left(\begin{array}{l} \text{Industrial} \\ \text{Methodology} \\ \text{Low Range Plus} \\ \text{High Range} \end{array} \right)$$

The industry total average cited at the end of the canned and frozen sections was taken directly from Reference 92.

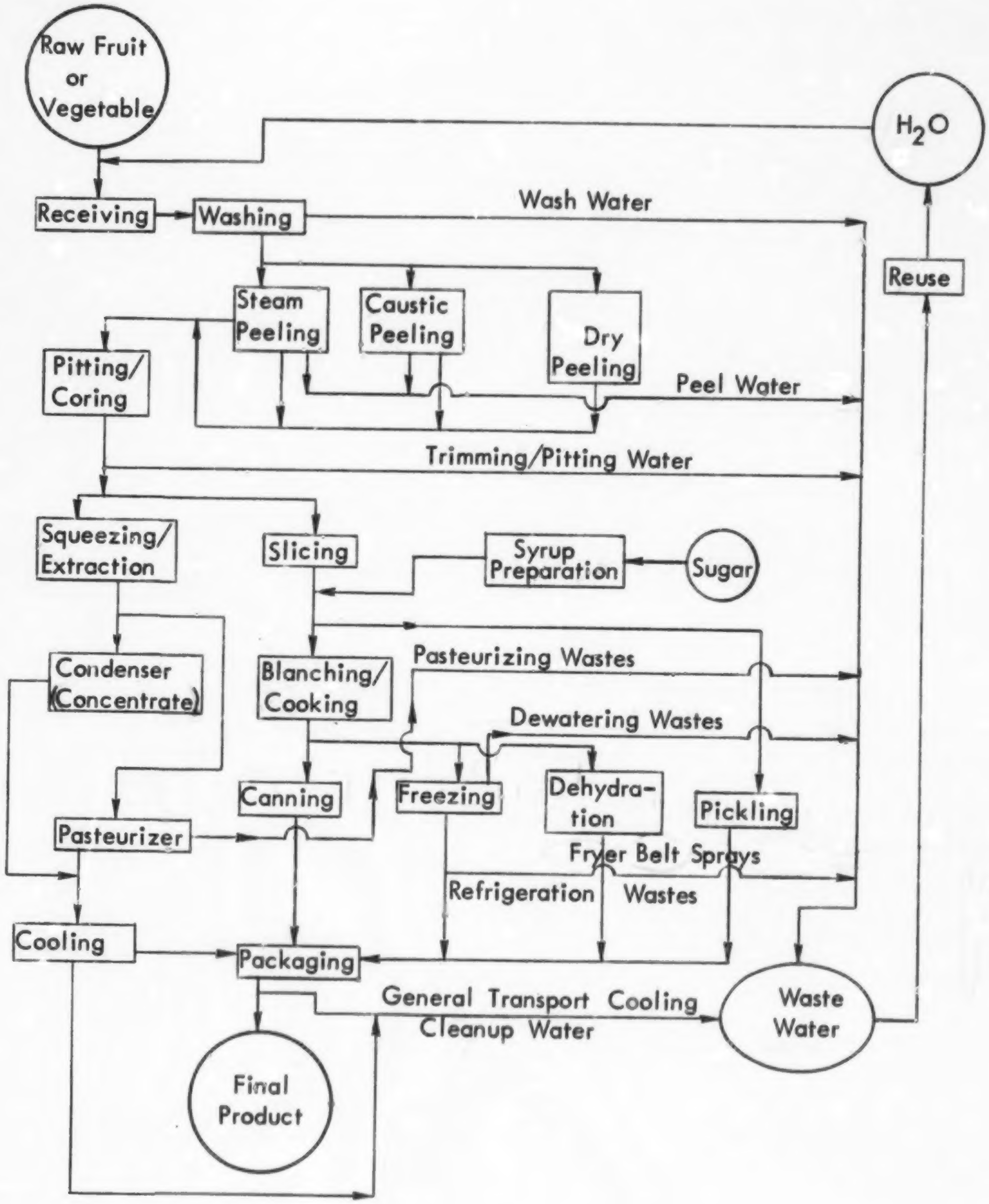

Raw Fruit or Vegetable
H$_2$O
Receiving
Washing
Wash Water
Reuse
Steam Peeling
Caustic Peeling
Dry Peeling
Pitting/ Coring
Peel Water
Trimming/Pitting Water
Squeezing/ Extraction
Slicing
Syrup Preparation
Sugar
Condenser (Concentrate)
Blanching/ Cooking
Pasteurizing Wastes
Dewatering Wastes
Canning
Freezing
Dehydration
Pickling
Pasteurizer
Fryer Belt Sprays
Refrigeration
Wastes
Cooling
Packaging
General Transport Cooling
Cleanup Water
Waste Water
Final Product

FIGURE VII-1
INDUSTRY SCHEMATIC:
CANNED AND PRESERVED
FRUITS AND VEGETABLES

TABLE VII-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 203

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Canned fruits and vegetables		10^6 equiv. cases	1950 1954 1963 1965/66	440 477 550 589					92	1967
Frozen fruits and vegetables		10^6 equiv. cases	1950 1954 1963 1965/66	104 196 260 355					92	1967
Potatoes	Processed other than frozen or canned	Percent of total processed			32				161	1973
Apples	Processed other than frozen or canned	Percent of total processed			33				161	1973
Cherries	Processed other than frozen or canned	Percent of total processed			23				161	1973

TABLE VII-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 203

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Peaches	Processed other than frozen or canned	Percent of total processed			2				161	1973
Pickles	Processed other than frozen or canned	Percent of total processed			100				161	1973
Fruits and vegetables	Canned	kg/cap/year	1950	35					161	1973
			1955	35						
			1960	38						
			1965	38						
			1968	40						
	Frozen	kg/cap/year	1950	3					161	1973
			1955	7						
			1960	9						
			1965	10						
			1968	12						
	Rubbish burned	10^3 metric tons			99				161	1973

TABLE VII-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 203

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Processed potatoes		kg/cap/yr	1960	10	28		43		183	1972
Citrus		kg/cap/yr	1967	24					162	1973
					37			48	139	1973
Apples		kg/cap/yr	1969	7	12.6				182	1972
			1972	7					162	1973
Vegetables w/o potatoes		kg/cap/yr.	1960	24				59	139	1973
			1972	45						
Population		10^6 residents	1970	203.2		213.9	224.1	235.7	136	1972
			1973	210.5						

TABLE VII-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 203

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Fruits and vegetables	Frozen and dehydrated	10^6#303 case equiv.	571	g	711	g	1015	g	1257	g
	Canned	10^6#303 case equiv.	658	g	778	g	844	g	902	g
	Total	10^6#303 case equiv.	1229	g	1489	g	1859	g	2159	g
	Rubbish burned	metric tons x 10^3	99	161	121	h	151	h	175	h
Raw weight basis (by product)										
Potatoes		kg/cap/yr	28	183	34	34	43	183	43	a
Citrus			37	139	40	b	44	b	48	139
Apples			6	182	6	c	7	c	8	c
Vegetables w/o potatoes			40	d	48	d	53	d	59	139
Total			111		128		147		158	

TABLE VII-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 203

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Raw weight basis (by process)										
Frozen and dehydrated		kg/cap/yr	34	e	41	e	56	e	66	e
Canned		kg/cap/yr	77	e	87	e	90	e	92	e
Frozen and dehydrated		10^6 kg/yr	1,088	f	8,829	f	12,605	f	15,609	f
Canned		10^6kg/yr	15,761	f	18,624	f	20,229	f	21,596	f
Population		10^6 residents	205.6	136	213.9	136	224.1	136	235.7	136

TABLE VII-4 (Cont.)

a. Linear interpolation of 1971 and 1980 per-capita data from Table VII-3. Assumed constant after 1980 because of low forecast level of remaining fresh potato consumption.

b. Linear interpolation of 1971 and 1985 data from Table VII-3.

c. Linear interpolation of 1969, 1971, and 1977 data from Table VII-3.

d. Linear interpolation of 1972 and 1985 per-capita figures from Table VII-3.

e. Percentage breakdown of total row above based on linear extrapolation of trends in canned vs. frozen from Reference 161 in Table VII-3. Frozen also includes 30 percent of potato pack which is dehydrated or made into chips.

f. Derived by multiplication of total frozen and canned per-capita figures above times population growth forecast in previous row.

g. Forecasts in millions of #303 case equivalents extrapolated from case output history from Reference 92 in Table VII-3. Growth in 1966 to 1971 was calculated from 1963 to 1966 growth rate. Growth in 1971 to 1985 was based on increases in total kilograms explained in footnote (f) above.

h. Base-year data from Reference 161 is 1971. Figures for 1975-1985 calculated assuming a constant ratio of rubbish burned to total #303 case equivalent output.

Potatoes. The demand for potatoes and potato products has changed markedly during the past decade. Annual per-capita consumption (fresh and processed combined on a fresh-weight equivalent basis) rose from 49 kg in 1960 to 54 kg in 1970. The increase is credited entirely to processed use, which rose from 11 kg in 1960 to 27 kg in 1970. In contrast, per capita fresh potato consumption fell from 39 to 27 kg.[183]

Among the processed potato products, use of frozen french fries has shown the greatest increase. In 1960, per-capita consumption of frozen potatoes was 3 kg. In 1971, consumption had reached 13 kg, nearly half of all processed potatoes, compared to only 28 percent in 1960. Further gains in the use of frozen french fries have occurred since 1970. The estimated per-capita consumption was 15 kg in 1972.[183]

Other processed potato products have registered smaller but substantial gains. For example, potato chip consumption per person increased in absolute terms, but declined relative to other potato products. Potato chips increased from 5 to 8 kg, but accounted for approximately 50 percent of all processed potatoes in the early 1960's, declining to 30 percent in 1970. Dehydrated potato use has also risen recently from 2.3 kg per capita in 1960 to 6 kg in 1970; it has accounted for about 20 percent of all processed potatoes. Consumption of canned potatoes has remained small and constant, less than 0.5 kg throughout the decade.[183]

Demand for potatoes is projected to increase in coming years, due mainly to population growth, continued increases in disposable personal income, and the shift in consumer preference towards processed consumer products. Available projections indicate that per-capita consumption of processed potato products will amount to 43 kg by 1980, approximately 75 percent of the total food use of potatoes in that year. In addition, exports of processed potato products may continue to increase during the 1970's. This level should remain constant after 1980, as per-capita fresh potato consumption will, by that time, be quite low. The percentages of processed potatoes that are frozen is 45 percent; dehydrated 20 percent; canned and other, 5 percent; and made into potato chips, 30 percent.[162] It may be assumed that at present the relative percentages are more or less in equilibrium, and will remain constant until 1985.

Canned and Frozen Fruits. The proportions of the total United States fruit crop accounted for by citrus fruits and apples in 1968 were 63.5 and 8.2 percent, respectively. These two classes of fruits also generated the major share of residuals when processed into canned and frozen forms.[161] The discussion in this section will thus be limited to these two segments of the fruit industry.

Total U. S. output of citrus fruits has grown steadily in the past decade, accounting for the major share of the increase in per-capita fruit consumption. As shown in Table VII-3, per-capita consumption of citrus fruits has grown from 38 kg in 1967 to 53 kg in 1971, an increase of 40 percent.[162] During this period, a shift in the use of citrus from fresh to processed forms, including frozen, chilled and canned, has occurred; by 1971, processed citrus fruits accounted for a 71 percent share of the total demand for citrus, in contrast to a 1967 share of 65 percent.[162]

The U. S. Department of Agriculture has forecast that per-capita use of processed citrus products will rise to about 105 lbs in 1985.[139] At this rate of growth, total production of processed citrus fruits will amount to 11,240 million kg in 1985. This growth trend, which has been used as the basis for establishing forecasts for 1975 and 1980, appears to agree with the forecast of total processed citrus of 9,072 kg in 1977, previously cited.[162]

The apple crop occupies a sizable share of the total U. S. fruit crop, accounting for about 8 percent. The share of the U. S. apple crop consumed as fresh fruit has been relatively stable in recent years, while processed apples have shown a slight upward trend.[182] Within the group of processed apple products, apple juice and apple wines have increased substantially, while use of canned apples, applesauce and frozen and dried apple products has failed to show any real growth.[182] Total production of the apple crop has declined by 5 percent since 1969, but this declining trend is predicted to be reversed in the near future.

The forecasts advanced in Table VII-4 are based on a projection of 1,453 million kg of processed apples in 1977.[162] This growth trend is based on the assumption that increased demand for apple juice and apple wines is expected to exert an upward pressure on apple production. Per-capita consumption of processed apples will be expected to reach 8 kg in 1985, or a total of 1,905 million kg, about 51 percent of total apple use. Fresh apple consumption per capita is assumed to stabilize at the current level of 7 kg. Forecasts for 1975, 1980 and 1985 have been established using the assumed trends mentioned above.

Canned and Frozen Vegetables without Potatoes. United States consumption of vegetables in recent years has stabilized, with consumption favoring processed forms. Total production of vegetables has averaged about 19,051 million kg in 1970-72. For 1972, annual per-capita consumption of processed vegetable products had increased to 45 kg from a 1960 level of 24 kg, an increase of 85 percent.

Per-capita use of canned and frozen vegetables is projected to reach about 59 kg in 1985, while consumption of fresh vegetables is expected to fall to about 40 kg.[139] These forecasts, as shown in Table VII-4, should result in a total production of vegetables of 23,550 million kg, or 100 kg per capita, in 1985, of which processed items will account for 13,916 million kg, or about 60 percent.

Discharge Inventory of Pollutants Capable of Producing Solid Waste. Table VII-5 presents estimated uncontrolled pollutant discharges in this sector obtained by multiplying the uncontrolled discharge rates by estimated industry production in the forecast years. Water pollutants are the major discharges. As shown in Table VII-5, suspended solids discharges are forecast to increase from 394 to 669 million kg between 1971 and 1985, and BOD_5 discharges are estimated to increase from 351 to 600 million kg during the same period. Particulate discharges to the air, by comparison, are insignificant, accounting for only

TABLE VII-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 203

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
AIR POLLUTANTS						
Particulates:						
Solid waste burned	Single chamber incineration	169	0.742	0.915	1.132	1.312
WATER POLLUTANTS						
Suspended Solids:		192				
Frozen and dehydrated			155	194	276	342
Canned			239	282	306	327
Total			394	476	582	669
BOD$_5$:		192				
Frozen and dehydrated			142	177	253	314
Canned			209	247	268	286
Total			351	424	521	600

1.3 million kg by 1985, even assuming the highly-polluting single chamber incinerator. The confidence level in this section is 2, indicating a ±50 percent possible variation in the data.

Likely Pollution Treatment Processes: Water Pollutants.

Table VII-6 summarizes the alternative treatments for water pollutants from canned and preserved fruits and vegetable plants capable of producing solid waste residues when treated. Figure VII -2 illustrates these treatments in a schematic fashion in order to clarify their relationship to one another. The range of efficiencies encountered and the estimated ratio of solid residues to the dry weight of solids removed is also given. It is clear from Table VII -6 that the efficiency of any given system varies with the product and the waste stream treated. Where large solids are contained in wastes some systems will plug up, requiring pre-treatment, usually screening and sometimes sedimentation.[162] Some waste streams are used to irrigate agricultural land and thus reduce the need for secondary treatment. Some waste streams may eventually seal off the soils on which they are being spread, placing a limit on this type of disposal.[244] Excessive application of treatment sludges to land may create problems and requires the addition of lime to the soil. Lagoons are predicted to create no solid wastes. Their proper operation will eliminate the need for dredging because of the high organic content of food industry wastes.[162]

The efficiency of the process changes in reducing the pollutant load varies. Most of these methods eliminate water discharges and directly yield solid wastes. These residues are included with the residues from air and water pollution control, as the primary justification for these new processes will be to reduce the waste load. Proposed methods to reduce future waste loads in compliance with the 1983 water standards to be established based on the 1972 amendments to the Clean Water Act include:[162]

1) Recycling of wash water.
2) Utilization of low water or dry peeling methods.
3) Improved mechanical cleaning of belts to replace belt wash water.
4) Recirculation of cooling water through cooling towers or spray ponds.
5) Extensive dry cleanup to replace washing and possible use of continuous dry cleanup and recovery procedures.

Table VII-7 presents typical costs in dollars per metric ton for the most likely treatments by plant type and size. The figures vary greatly and in almost all cases indicate a heavier burden for the smaller plants.[162]

Table VII -8 presents the proposed effluent guidelines for apple, citrus, and potato processing plants.[162] The raw waste load in units of kg/kkg of product was compared with the proposed standards for 1977 and 1983 in order to estimate control percentages. These figures will be used to predict controls for the entire industry in Tables VII-11 to VII-14.

TABLE VII-6
LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE[162]
SIC 203

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (percent)	Kg Residue (Dry) Per Kg (Dry) Removed
Primary systems		SS	Preliminary screening	60-80	1
		SS	Grease traps	40-50	1
		BOD_5	Grease traps	30	--
		Grease	Grease traps	40-50	1
		SS	Sedimentation	30-75	1
		BOD_5	Lime coagulation	42-89	--
		SS	Lime coagulation	81	1.1
		SS	Coagulation and sedimentation	40-70	1.1
Secondary systems	Apple	SS	Multiple aerated lagoons	70	0
	Citrus		Multiple aerated lagoons	75	0
	Potato		Multiple aerated lagoons	91	0
	Apple		Activated sludge	30	0.5
	Citrus		Activated sludge	74	0.5
	Potato		Activated sludge	30	0.5

TABLE VII- 6 (Cont.)
LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE[162]
SIC 203

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (percent)	Kg Residue (Dry) Per Kg (Dry) Removed
Secondary systems (Cont.)	Citrus	SS	Aerobic & anaerobic lagoon	40	0.1
	Potato			81	0.1
	Apple		Aerobic lagoon and trickling filter	91	0.2
	Citrus			90	0.2
	Potato			90	0.2
	Potato		Trickling filter	66	0.45
Advanced systems		SS	Filtration	90	1
			Additional aeration	90	--
Process changes		SS		Varies	~0.9
	Dry peeling				1
	Mechanical cleanup				1
	Recycle of wash water				<1

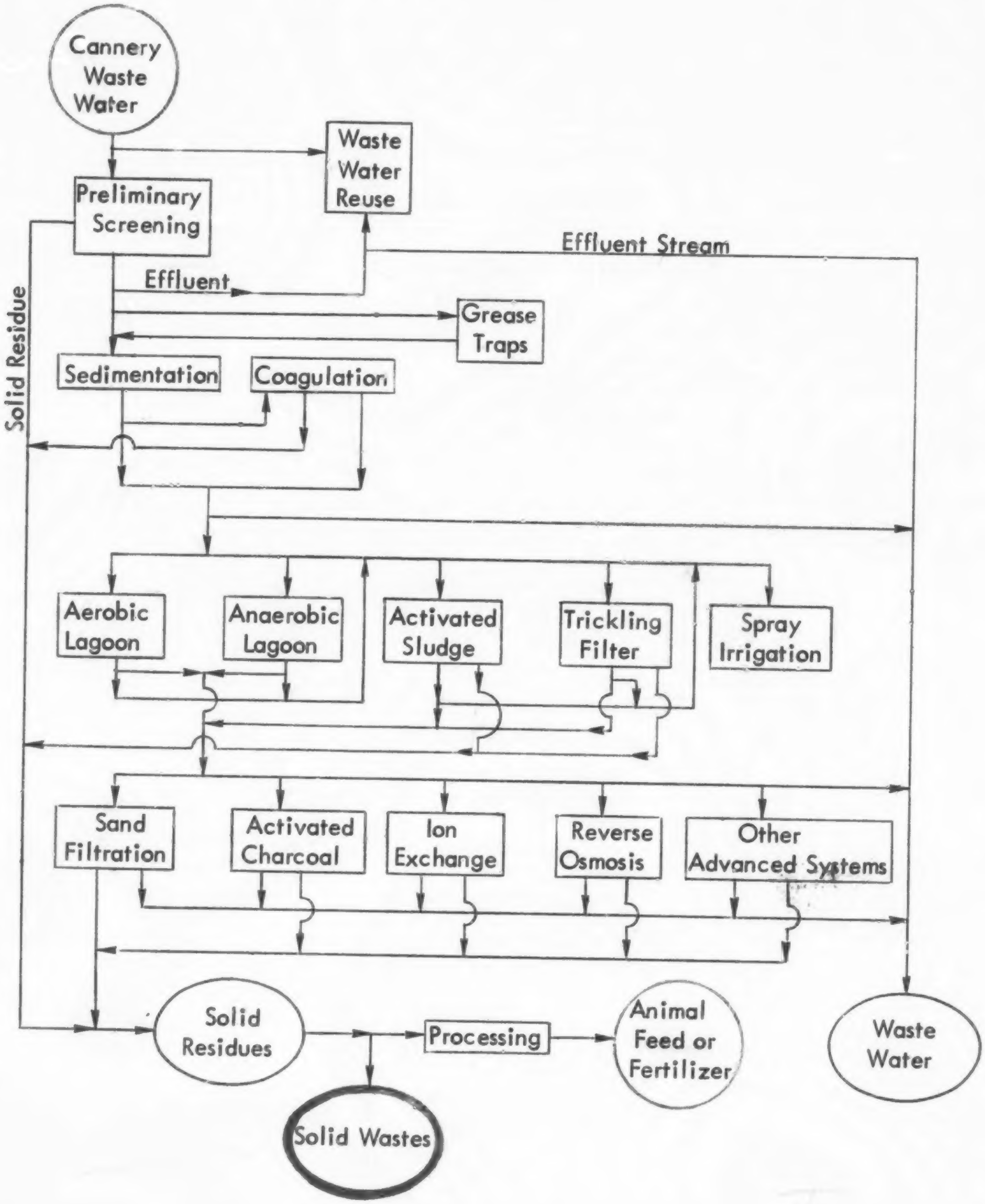

Cannery Waste Water
Waste Water Reuse
Preliminary Screening
Effluent Stream
Effluent
Grease Traps
Solid Residue
Sedimentation
Coagulation
Aerobic Lagoon
Anaerobic Lagoon
Activated Sludge
Trickling Filter
Spray Irrigation
Sand Filtration
Activated Charcoal
Ion Exchange
Reverse Osmosis
Other Advanced Systems
Solid Residues
Processing
Animal Feed or Fertilizer
Waste Water
Solid Wastes

FIGURE VII-2
WATER TREATMENT PROCESS SCHEMATIC:
CANNED AND PRESERVED FRUITS
AND VEGETABLES

TABLE VII -7

WATER POLLUTION TREATMENT COSTS IN TYPICAL CANNED AND PRESERVED FRUITS AND VEGETABLES PLANTS[162][a]

Plant	Kkg/Year Capacity at 260 Days/Year	Treatment: $/Metric Ton						
		Preliminary Screening	Sedimentation Residue		Aerobic Lagoon w/Settling	Anaerobic/ Aerobic Ponding	Trickling Filter	Activated Sludge
			No Disposal	Disposal				
1. Apple slices & juice								
Small	23,582	0.04	0.13	0.18	0.39	0.72	0.17	0.36
Large	235,820	0.01	0.05	0.04	0.08	0.14	0.10	0.13
2. Apple juice								
Small	23,582	0.01	0.06	0.13	0.25	0.01	0.13	0.21
Large	117,910	0.01	0.02	0.04	0.09	0.09	0.05	0.09
3. Citrus, juice, oil, seg.								
Small	94,328	0.02	0.10	0.08	0.17	0.27	0.17	0.25
Large	943,280	0.01	0.05	0.03	0.06	0.11	0.11	0.11
4. Citrus - peel								
Small	94,328	0.02	0.09	0.08	0.16	0.23	0.15	0.22
Large	943,280	0.01	0.02	0.06	0.03	0.06	0.04	0.05
5. Citrus juice, oil, seg. & peel								
Small	94,328	0.04	0.17	0.13	0.24	0.17	0.32	0.41
Large	943,280	0.01	0.08	0.05	0.08	0.15	0.14	0.18
6. Potatoes - dehydrated								
Small	47,164	0.03	0.16	0.14	0.30	0.42	0.28	0.36
Large	141,492	0.03	0.13	0.10	0.18	0.37	0.25	0.31
7. Potatoes - frozen								
Small	82,550	0.04	0.20	0.13	0.27	0.53	0.36	0.44
Large	235,820	0.03	0.15	0.10	0.17	0.35	0.28	0.36

TABLE VII -7 (Cont.)
WATER POLLUTION TREATMENT COSTS IN TYPICAL CANNED AND PRESERVED FRUITS AND VEGETABLES PLANTS[162][a]

[a] Data were originally expressed in \$/year/plant in Reference 162. They were converted to \$/m ton by using the plant capacity per day figures given in the above reference and assuming a 260 work-day year. Since many food plants are seasonal, these figures may be low.

TABLE VII-8
FUTURE REQUIRED TREATMENT LEVELS IN THE CANNED AND PRESERVED FRUITS AND VEGETABLES INDUSTRY
SIC 203

	BOD_5(kg/kkg)					SS (kg/kkg)				
Plant Subcategory	Raw[162]	1977 Guideline[162]	% Reduction	1983 Guideline[162]	% Reduction	Raw[162]	1977 Guideline[162]	% Reduction	1983 Guideline[162]	% Reduction
Apples: Slices and sauce	10.5	0.35	96.7	0.07	99.3	2.95	0.25	91.5	0.04	98.6
Apples: Juice	2.05	0.25	88	0.02	99.0	0.3	0.15	50	0.02	93.3
Citrus: Juice, oil, segments										
Small plants	3.55	0.30	91.5	0.03	99.2	0.35	0.15	57	0.9	97.1
Large plants	2.8	0.25	91.1	0.03	98.9	1.2	0.15	88	0.01	99.2
Citrus: Peel products	1.35	0.20	85	0.01	99.2	0.40	0.20	50	0.01	97.5
Potatoes: Dehydrated	17.3	0.60	96.5	0.15	99.1	13.4	1.20	91.0	0.13	99.0
Potatoes: Frozen products										
Small plants	27.4	1.00	96.4	0.21	99.2	23.7	1.50	93.7	0.15	99.4
Large plants	15.0	0.95	94	0.21	98.6	25.1	1.50	94.0	0.15	99.4
Mean for all plants			--		--			80		98

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Out of 9,209 thousand metric tons of food processing plant solid residues, 7,300 tons were reused, almost totally as animal feed ingredients.[161] The treated wastewater solids and sludges are rich in nutritional value[162] and, if not contaminated with pesticides, may be useful for feed. Their reuse potential is likely to be similar to solid residues from food plants as a whole: 7,300 tons/9,109 tons or approximately 80 percent reused. Tables VII-9 and VII-10 present the current utilization of solid residues in the food industry.

No reuse of residues from advanced treatment is forecast, as the small amounts of waste and the wastes from media such as activated carbon and sand filters will reduce the value of the residues produced. The data in this section can be given a confidence level of 3, indicating a ±25 percent variation in the final reuse percentages.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables VII-11 to VII-14 forecast the total solid wastes from air and water pollution control for 1971, 1975, 1980, and 1985, respectively. Air pollutant residues, even assuming no reuse, are insignificant. The tables calculate residues from suspended solids by presenting primary, secondary, and advanced trearment in steps following any reductions from process changes. At each step the percent of the suspended solids remaining in the effluent for further treatment is given. The tables are consistent with the suggested effluent guidelines cited in Table VII-8, yielding 79.3 percent efficiency in 1971, 86 percent efficiency in 1979, 91.3 percent efficiency in 1980 and 98 percent efficiency in 1985. The forecast average treatment loads are higher than the suggested effluent guidelines until 1985, because the guidelines are minimums which must be met. Many plants already meet the 1977 guidelines and some already approach the required 1983 treatment levels. Land application of effluents is the major way most plants are currently meeting the 1977 guidelines. For plants which cannot economically dispose effluents to agricultural land, increased secondary treatments will be necessary by 1977. The confidence level of this final forecast is 2, indicating a ±50 percent possible variation in the data. Total wastes to landfills are forecast to increase from 51.4 million kg in 1971 to 127.5 million kg in 1985. The residues will be primarily organic matter and should pose very few problems at landfill sites.

Composition of Solid Waste Residues from Pollution Treatment Processes.

The solid waste residues from pollution treatment processes in the Canned and Preserved Fruits and Vegetables Industry consist of organic materials such as vegetable fragments, starch grains (amyloplasts), and sludge microbial masses. The composition of such residuals was calculated from the ratio of SS to BOD_5 in wastewater, and assuming a 98 percent reduction in SS and BOD_5 due to primary and secondary treatments (see Table VIII-8). The treated SS adds to the mass of residual wastes while the BOD_5 reduces it. Table VII-15 lists the estimated composition of solid waste generated from pollution control in this sector.

TABLE VII-9
SOLID RESIDUE DISPOSITION IN THE FOOD INDUSTRY[161]

Thousands of tons of solid residuals handled[a]

As Solid Waste				In Liquid Waste					By-product			Not Accounted For
Fill	Spread	Burn	Total	Water	Pond	Sewer	Irr.	Total	Main	Other	Total	
Food												
822	830	18	1,670	102	24	108	5	239	7,080[b]	220	7,300	1,010
Non-food												
300	17	97	414	--	32	--	--	32	134[c]	67	201	--
Total												
1,122	847	115	2,084	102	56	108	5	271	--	--	7,500	1,010

[a] Significant contributions due to fish processing have been subtracted from data given in Ref. 161.

[b] Feed.

[c] Metal.

TABLE VII- 10
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 203

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Particulates					
Solid waste burned	Single chamber	Air controls	0		Ash
Suspended solids					
	Process modifications		80	161	Organic food wastes
	Primary treatment		80	161	Organic food wastes
	Secondary treatment		80	161	Biological sludge
	Advanced systems		0	162	Organic food wastes and spent carbon or sand filter material

TABLE VII-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 203

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Solid waste burned	Single chamber incineration		100	1	90	1	100	1
Total Residues from Air Pollution Control:				1		1		1
WATER POLLUTANTS								
Suspended solids:	Process modifications		0					
			[SS remaining in effluent = 100%]					
	Primary treatment	Preliminary screening	60	240	60	140	20	30
		Screening & sedimentation	10	40	75	30	20	6
		Coagulation & sedimentation	10	40	75	30	20	6
		None	20	0				
		Total	100	320	(50)[a]	200		40
			[SS remaining in effluent = 49%]					

TABLE VII-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 203

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended Solids: (Cont.)	Secondary treatment	Trickling filter	5	4	66	3	20	1
		Aerated lagoon	2	0.4	75	negl.	20	negl.
		Activated sludge	2	2	60	1	20	negl.
		Aerated lagoon & trickling filter	1	0.4	90	negl.	20	negl.
		None	90	0				
		Total	100	6	(7)[a]	4		1
			[SS remaining in effluent = 42.1%]					
	Advanced systems		1.6	2/63	90	2	100	2
			[SS remaining in effluent = 40.7%]					
	Effluent land treatment		20	0	100		0	0
			[SS remaining in effluent = 20.7%]					
Total Residues from Water Pollution Control:				330		210		45
Total Residues from Air and Water Pollution Control:				330		210		45

---

[a] Figures in parentheses are percent control, which is the weighted average of the above treatment efficiences with their corresponding percentage application. This figure takes into account that percentage of pollutant to which no treatment is applied.

TABLE VII-12
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 203

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Solid waste burned	Single chamber incineration		100	1	90	1	100	1
Total Residues from Air Pollution Control:				1		1		1
WATER POLLUTANTS								
Suspended solids:	Process modifications		0 [SS remaining in effluent = 100%]					
	Primary treatment	Preliminary screening	60	290	60	170	20	30
		Screening & sedimentation	15	70	75	50	20	10
		Coagulation & sedimentation	10	50	75	40	20	8
		None	15	0	0			
		Total	100 [SS remaining in effluent = 45%]	410	(53)[a]	260		50

TABLE VII-12 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 203

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)	Secondary treatment	Trickling filter	7	7	66	5	20	1
		Aerated lagoon	2	0.4	75	negl.	20	negl.
		Activated sludge	2	2	60	1	20	negl.
		Aerated lagoon & trickling filter	4	2	90	2	20	negl.
		None	85	0				
		Total	100	10	(12)[a]	8		1
			[SS remaining in effluent = 31%]					
	Advanced systems		2.2	3	90	3	100	3
			[SS remaining in effluent = 29%]					
	Effluent land treatment		15	0	100		0	
			[SS remaining in effluent = 14%]					
Total Residues from Water Pollution Control:				420		270		50
Total Residues from Air and Water Pollution Control:				420		270		50

[a] Figures in parentheses are percent control, which is the weighted average of the above treatment efficiences with their corresponding percentage application. This figure takes into account that percentage of pollutant to which no treatment is applied.

TABLE VII-13
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 203

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Solid waste burned	Single chamber incineration		100	1	90	1	100	1
Total Residues from Air Pollution Control:				1		1		1
WATER POLLUTANTS								
Suspended solids:	Process modifications		20	100	20	20	20	4
			[SS remaining in effluent = 96%]					
	Primary treatment	Preliminary screening	70	340	60	200	20	40
		Screening & sedimentation	15	80	75	60	20	10
		Coagulation & sedimentation	15	80	75	60	20	10
		None	0	0				
		Total	100	500	(64)[a]	320		60
			[SS remaining in effluent = 35.5%]					

TABLE VII-13 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 203

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)	Secondary treatment	Trickling filter	15	10	66	7	20	1
		Aerated lagoon	15	3	75	2	20	negl.
		Activated sludge	15	20	60	10	20	2
		Aerated lagoon trickling filter	25	10	90	9	20	2
		None	30	0				
		Total	100	40	(53)[a]	30		5
			[SS remaining in effluent = 16.8%]					
	Advanced systems		10	10	90	9	100	9
			[SS remaining in effluent = 15.1%]					
	Effluent land treatment		50	0	100		0	0
			[SS remaining in effluent = 7.6%]					
Total Residues from Water Pollution Control:				650		360		70
Total Residues from Air and Water Pollution Control:				650		360		70

---

[a] Figures in parentheses are percent control, which is the weighted average of the above treatment efficiences with their corresponding percentage application. This figure takes into account that percentage of pollutant to which no treatment is applied.

TABLE VII-14
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 203

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Solid waste burned	Single chamber incineration		100	1	90	1	100	1
Total Residues from Air Pollution Control:				1		1		1
WATER POLLUTANTS								
Suspended solids:	Process modification		80	480	40	190	20	40
			[SS remaining in effluent = 68%]					
	Primary treatment	Preliminary screening	70	320	60	190	20	40
		Screening & sedimentation	15	70	75	50	20	10
		Coagulation & sedimentation	15	70	75	50	20	10
		None	0	0				
		Total		940	(51)[a]	480		100
			[SS remaining in effluent = 24.1%]					

TABLE VII-14 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 203

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)	Secondary treatment	Trickling filter	20	10	66	10	20	2
		Aerated lagoon	20	23	75	2	20	negl.
		Activated sludge	15	8	60	5	20	1
		Aerated lagoon & trickling filter	35	10	90	9	20	2
		None	10	0				
		Total	100	30	$(90)^a$	30		5
			[SS remaining in effluent = 7.5%]					
	Advanced systems		60	30	90	30	100	30
			[SS remaining in effluent = 3.5%]					
	Effluent land treatment		50	0	100		0	
			[SS remaining in effluent = 1.8%]					
Total Residues from Water Pollution Control:				1,000		540		140
Total Residues from Air and Water Pollution Control:				1,000		540		140

---

[a] Figures in parentheses are percent control, which is the weighted average of the above treatment efficiences with their corresponding percentage application. This figure takes into account that percentage of pollutant to which no treatment is applied.

TABLE VII-15

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 203

Item: Canned and Preserved Fruits and Vegetables

Process or Activity: A11

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	40	See text
Volume	l --wet	40	
H_2O content (of wet weight)	%	40	
Combustible	kg	0.7	
Non-combustible	kg	0.3	
Ash content	kg	0.3	
Liquid form	kg	40	
Solid form	kg	1	
Energy content	kcal		
Oxygen requirements	kg BOD_5	0.02	
Valuable metals	kg		
Volatile	kg	0.7	
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg	0.7	
Non-biodegradable	kg	0.3	

In 1971, 0.68 kg BOD_5 per kg SS was discharged (see Table VII-5). The sludge is 95 to 98 percent water;[162] the ash content of the dry solids is assumed to be similar to animal manure (see Section IV, Animal Feedlots), approximately 30 percent by weight. It should be noted that, although the BOD_5 content is low, the COD may still be quite high, as the residue is very high in organic matter.

If tertiary treatment by carbon adsorption is practiced, and the carbon is not reused, the residual will be essentially carbon; the same is true in the case of sand filtration. However, carbon may be reactivated and reused, and sand may be cleaned and reused. Hence, these components are not included in the estimate of solid waste residue composition.

Factors Affecting the Quality of the Data.

The widely varying methods used for canneries across the country make the estimates of pollution discharges from a typical plant somewhat uncertain. The estimates of future growth trends in the industry are based on extensive historical data and should be more accurate. Aside from varying discharge factors and slightly uncertain economic growth through 1985, the major source of uncertainty is the types of treatment processes which will be used and the disposal techniques for the solid residues created from these treatments.

Spraying the effluent on agricultural land eliminates solid residue disposal in landfills of any pollutants remaining in the effluent. The degree of use of this method in the future is fairly uncertain. Also, the use of lagoons, which contribute only negligible amounts to solid wastes, is difficult to forecast. It is probable, given the above difficulties, that the estimates of solid waste generation from air and water pollution control in this industry are within ± 50 percent of the true values, indicating a confidence level of 2.

Summary.

Untreated Discharges. Air pollutant discharges from the Canned and Preserved Fruits and Vegetables Industry are minimal, the main source being incineration of solid waste. Considerable amounts of water pollutants, principally BOD5 and suspended solids, are generated from this sector. Most water pollutants are created early in industrial processing, particularly during the receiving, washing, peeling, pitting and coring steps. Canning processes account for a higher proportion of water pollutant discharges than do both freezing and dehydration together, but all three operations make significant contributions to uncontrolled discharges. Total uncontrolled BOD_5 discharges were forecast to increase from 351 million kg in 1971 to 600 million kg in 1985; total suspended solids discharges were forecast to show a similar increase, from 394 to 669 million kg, during the same period.

Treatment Methods and Reuse. Likely water pollution treatment processes to control BOD_5 and SS discharges are: preliminary screening, sedimentation, and lime coagulation (primary treatments); trickling filters, aerated lagoons, and activated sludge (secondary treatments); and effluent land application. Aerated lagoons and land application will produce few solid waste residues, while other processes will generally create residues of a weight equal to 1.0 to 1.3 times the weight of the pollutant removed. Limited application of advanced treatment systems was forecast by 1985. Although large amounts of solid waste are generated from this sector, both during processing and as a result of pollution control, their reuse potential is quite high; principal reuse application of solids is as animal feed. Approximately 80 percent of the residues generated from pollution control were forecast to be reused.

Residues Generated from Pollution Control: Types and Amounts. Total solid residues from pollution control (effectively water pollution control) were forecast to increase from 45.4 million kg in 1971 to 140.7 million kg in 1985; most of these wastes will subsequently be disposed to landfills. Most of the increase during this period can be attributed to a higher percentage of control, principally as a result of increased application of process modifications and advanced systems by 1985. The percentage of original suspended solids remaining in the final effluent following all treatment was forecast to decline from 21 percent in 1971 to only 2 percent by 1985. The solid waste residues from pollution control will be highly organic and contain considerable amounts of water; about 70 percent of the residues, by weight, were estimated to be biodegradable.

SECTION VIII

THE GRAIN INDUSTRIES
SIC 204

Introduction.

The grain industries are grouped under SIC 204. The SIC Code further divides the grain industries into seven sub-industries listed below:

2041	Flour and Other Grain Mill Products Industry
2043	Cereal Breakfast Food Industry
2044	Rice Milling Industry
2045	Blended and Prepared Flour Industry
2046	Wet Corn Milling Industry
2047	Pet Food Industry
2048	Prepared Food Industry

The following analysis includes all the grains processed in these industries, broken down by the types of grains and processes. The solid waste impact of pollution control in the grain industries will derive mostly from control of particulate discharges to the air.

Untreated Discharge Factors.

Air Pollutants. The pollution generated in SIC 204 is almost exclusively particulates. Plant and grain particles are the bulk of the weight of these particulates. The particles from different grains vary in size and density.

Air pollution discharge factors (see Table VIII-1) are as listed in Compilation of Air Pollutant Emission Factors.[169] In cases where the listed values were given after air pollution control via a cyclone, a 70 percent common efficiency of current cyclones was used to calculate uncontrolled emission.[10] Vandergrift estimates a total particulate production of 135 kg/kkg in all operations at grain elevators.[10]

Table VIII-1 lists uncontrolled discharges of particulates for various portions of the grain industries. Note that grain elevators generate considerable levels per unit of grain processed. Air pollution discharge rates may be given a confidence level of 3, indicating a ± 25 percent possible variation.

Water Pollutants. Most plants in grain milling, and selected segments especially, were found to be presently discharging to municipal treatment systems, so that individual treatment plant facilities will not be required. Consequently, only a limited number of plants are expected to be impacted by the proposed effluent limitation guidelines.[11,257]

Theoretically, almost all the particle matter trapped in air filters can be reused in later batches of the same process or, in some cases, in animal feed products. Realistically, it is sometimes too technically difficult or costly to store the residue until it can be reused. Federal Drug Administration rules restrict use of these residues where they are contaminated with feed, food additives, drugs or other potentially dangerous impurities.

TABLE VIII-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 204

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Shipping/ receiving	Country elevators	kkg	Particulates	2.5	169
Handling				1.5	
Screening/ cleaning				4.0	
Drying				3.5	
All related[c] processes	Grain elevators	kkg	Particulates	13.5	10
Shipping/ receiving	Terminal elevators	kkg	Particulates	0.5	169
Handling				1.0	
Screening/ cleaning				2.5	
Drying				3.0	
Corn mealing		kkg	Particulates	2.5	169
Soybean mealing				3.5	
Soybean oiling				3.5	
Wheat cleaning				0.3[b]	
Barley cleaning				0.3[b]	
Milo cleaning (sorghum)				0.7[b]	
Barley milling				5.0[b]	
Barley mealing				5.0[b]	
Corn wet-milling				4.0	

---

[a] For 1971 or most recent available information.

[b] Determined by 3.33 times the stated, controlled emission value. This assumes 70 percent efficiency for the cyclones.

[c] Average value for all grains, for all processes at the grain elevators.

Very little water pollution is generated in most phases of grain processing and handling. Most water pollution is composed of particles in the wash-water used to clean out grain cars. Wet corn processes and wet wheat milling produce some water pollution, but those industries are a small portion (less than 1 percent) of the total grain industry. Impacts of water pollution control on solid waste, since they are comparatively minimal, will not be discussed or evaluated in this Section.

Industry Description and Schematic.

The U.S. grain industry includes nine major grains. The range in weight of production among these major grains is very large. Except for silage, all grain is shipped from firms by one of two routes. Country elevators receive 83 percent of current production, from which it passes to a terminal elevator and then to processing. The remaining grain is passed directly to terminal elevators and then processed.

An average value for the pollution generated in both country and terminal elevators is listed as 13.5 kg/kkg[10]. This assumes a single screening, cleaning, and drying, with the shipping and handling values summed for both country and terminal elevators. This is close to standard practice. Of course such air pollution is via particulates.

Processing occurs soon after grain leaves the elevator. The pollution generated in processing is significantly less than that from grain elevators. Figure VIII-1 illustrates the basic grain handling and processing steps described above. Although most grain is stored in elevators, some may be sent directly to final processing operations. If grain is sufficiently dried in the field, the drying step may be by-passed. Most elevators and grain mills use moisture testers on all incoming loads.

All grain for human consumption is cleaned before use, but animal feed mills may accept good quality field grain without cleaning. In processing for human consumption some wet processes are used, although dry milling is predominate.

Economic Forecasts.

Production values for 1971 listed by the Economic Research Service and Statistical Reporting Service of the USDA are summarized in Table VIII-2.[402] These data are extrapolated in Table VIII-3 to predict industry production through 1985. Economic forecast data for grain mills can be given a confidence level of 4, indicating a ± 10 percent possible variation in the data.

The Economics of Clean Air estimates that an average, although erratic, annual growth rate of 3.5 percent will continue for many years.[89] Thus, the 1971 values may be considered to be accurate, but values for later years will be less precise.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

The processes used in this industry produce significant quantities of only particulates.

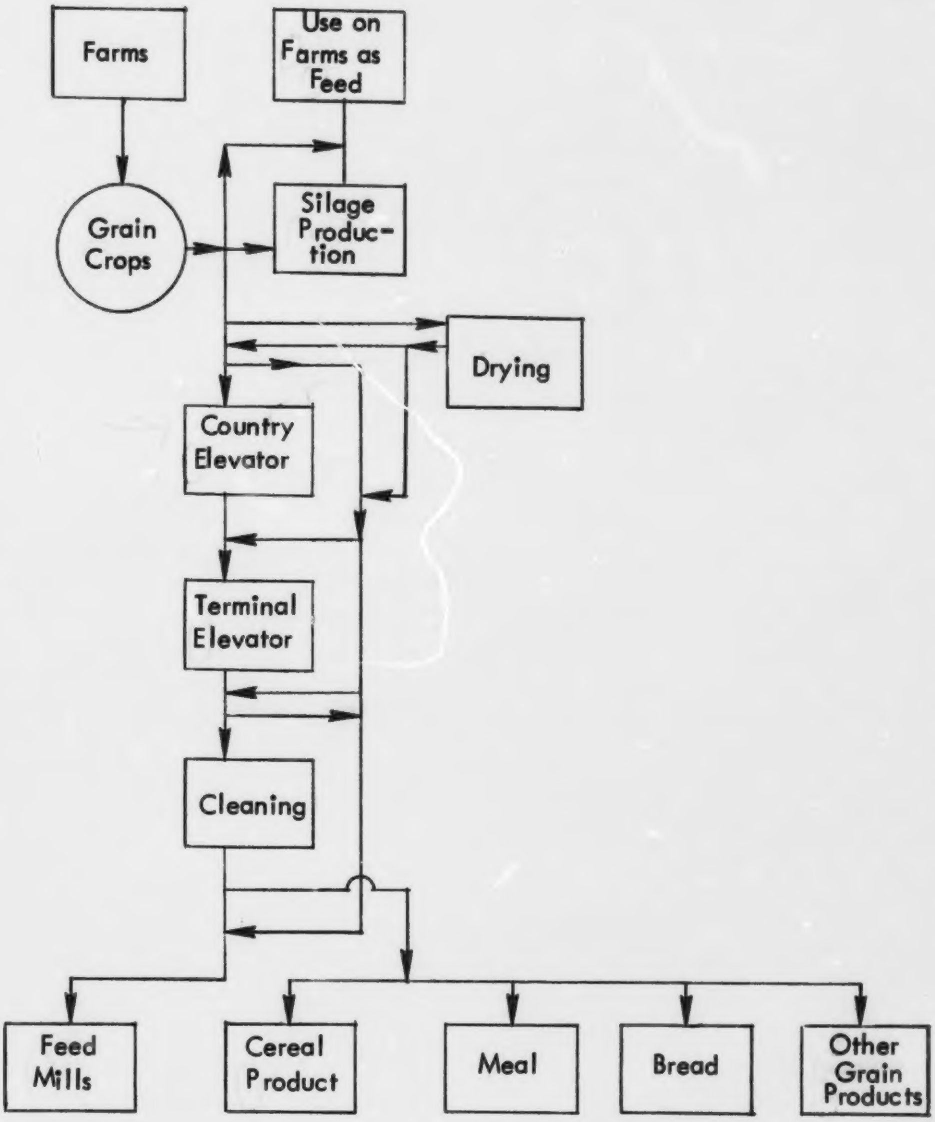

Farms
Use on Farms as Feed
Grain Crops
Silage Production
Drying
Country Elevator
Terminal Elevator
Cleaning
Feed Mills
Cereal Product
Meal
Bread
Other Grain Products

FIGURE VIII-1

INDUSTRY SCHEMATIC: GRAIN INDUSTRIES

TABLE VIII-2
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 204

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Corn:[a]		10^6 kkg	1972	148.99	142.33				402	1973
Food				13.00	12.68					
Cornmeal				3.80	3.80					
Wet process				7.61	7.29					
Alcohol				0.70	0.76					
Seed				0.51	0.54					
Feed				126.12	113.52					
Export				31.7	16.39					
Wheat:[b]		10^6 kkg			53.53				402	1973
Food					14.31					
Commercial feed					7.21					
Silage					1.99					
Seed					1.74					
Industrial										
Export					31.28					
Rice:		10^3 kkg	1972	421.0	41.90				402	1973
Food				11.80	11.60					
Industry				3.60	3.40					
Seed				1.30	1.10					
Export				25.40	25.80					
Barley:[c]		10^6 kkg			10.9				402	1973
Alcohol					2.40					

TABLE VIII -2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 204

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Barley: (Cont.)		10^6 kkg	1972						402	1973
Food					0.17					
Feed					6.26					
Seed					0.39					
Export					1.68					
Soybeans:[d]		10^6 kkg	1972	35.03	34.22				402	1973
Oil				3.59	3.75					
Export				11.32	11.80					
Feed				0.03	0.03					
Seed				1.39	1.31					
Meal				15.40	16.43					
Oats:[e]		10^6 kkg	1972	12.47	13.08				402	1973
Food				0.67	0.67					
Feed				10.69	11.34					
Seed				0.78	0.83					
Export				0.35	0.26					
Sorgham:[f]		10^6 kkg	1972						402	1973
Feed					22.73					
Silage					10.0					
Rye:[f]		10^6 kkg	1973	1.22	0.82				402	1973
Food				0.13	0.13					
Feed				0.51	0.41					

TABLE VIII-2 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 204

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Rye: (Cont.)		10^6 kkg	1973						402	1973
Seed				0.13	0.15					
Industry				0.08	0.08					
Export				0.38	0.05					
Safflower:		10^3 kkg	1970	22.2	24.9					

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[a] Calculated at 31.71 kg/bushel.

[b] Calculated at 27.2 kg/bushel.

[c] Calculated at 21.8 kg/bushel.

[d] Calculated at 27.2 kg/bushel.

[e] Calculated at 14.5 kg/bushel.

[f] Calculated at 25.4 kg/bushel.

TABLE VIII-3
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 204

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Handling & storage[a]	Train cars, grain elevators	10^6 kkg	301	402	345	b	410	b	487	b
Corn meal	Grain mills	10^6 kkg	3.8	402	4.4	b	5.2	b	6.2	b
Corn-wet process			7.3		8.4		9.9		12.0	
Barley meal/flour			6.4		7.3		8.7		10.0	
Soybean oil/meal			19.8		22.7		27.0		32.0	
Sorghum cleaning			22.7		26.0		30.9		36.7	
Flour & feed			184.0		211.0		251.0		298.0	

---

[a] This figure is all grain consumed (including imports) from Table VIII-2 minus ten million metric tons of sorghum silage. The corn consumption figures in Table VIII-2 were already net figures of corn used on farms.

[b] The future estimates are found by compounding the annual 3.5 percent growth rate from the 1971 U.S.D.A.-calculated production.

The weights of particulates generated annually for various processes are listed in Table VIII-4. As previously stated, the particulates are organic grain and plant residues.

Likely Pollution Treatment Processes.

Three methods of air pollution control are common. The fabric filter is the most likely choice for the future.[3] The method currently most frequently used is the cyclone, used for about 40 percent of grain processed. Centrifuges are occasionally used with starch and other wet corn processes.[166] Table VIII-5 describes these treatments.

The fabric filter achieves an average filtering efficiency of about 95 percent with high reliability and available technological methods. The cyclone has about 70 percent efficiency,[10] and it does not appear this efficiency can be increased significantly in the future. The gas centrifuge has 99.75 percent efficiency,[169] but its use is currently limited to wet corn processing. It is probable that the fabric filter will be increasingly adopted by the industry. Older and smaller plants will continue to use cyclone methods as long as possible, but will in all probability slowly change over to fabric filters. The gas centrifuge will probably remain in wet processes, but will continue to process less than one percent of the total weight of grain processed. A study of three model grain processing plants estimated pollution controls as about 9 percent of the total investment in plants.

Figure VIII-2 illustrates the treatment process alternatives in the grain industry and the fate of the residues created by control. Mills producing animal feed may simply recycle the wastes to the feed mixer if no problems of contamination with drugs or feed additives are present. Elevators and mills producing products for human consumption must sell the residues as by-products (generally for animal feed) or dispose them to the land. The reuse of residues is becoming easier because terminal storage is increasingly being performed on or near the mills which process the final product. Also, most elevators are in areas with large farm animal populations which may be able to consume the waste residues.

Although some incineration has been practiced in the past, increasingly stringent bans on burning have forced these wastes toward more land disposal. Treatment process data for grain mills can be given a confidence level of 4, indicating a ± 10 percent variation in the data.

Reuse Potential for Solid Waste Residue Produced by Pollution Treatment Method.

Particulate air pollutants are mostly pieces of grain and plant useful for most non-human food purposes . The F.D.A. restricts the use of the residues for human food processing and restricts hormones and drugs in animal feeds. The cost of storing residue from final batches may force it to be disposed rather than stored or reused. A rough estimate is that anywhere from 50 to 95 percent of the residue is reused. In the future, the continuing use of large mills will increase reuse possibilities; the capture of

TABLE VIII-4
DISCHARGE INVENTORY BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 204

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Particulates	Grain elevators[a]	10	4070	4670	5550	6590
	Corn meal	169	10	11	13	16
	Wet process	169	29	33	40	47
	Barley meal/flour	169	32	37	44	50
	Soybean meal/oil	169	69	79	94	112
	Sorghum cleaning	169[h]	16	18	22	26
	Flour and feed	169	644	739	878	1042
Total			4870	5588	6641	7883

[a] Assumes all grain except that used on the farm stored at a county elevator and then stored at a terminal elevator where it is screened and cleaned.

[b] Estimate of 3.5 kg/kkg based on corn, soybean and barley mealing discharges, as no direct estimates of flour and feed emissions were available.

TABLE VIII-5

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 204

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Handling/ processing[a]		Particulates	Cyclone	70	1		10
Handling/ processing[a]		Particulates	Fabric filter	95	1	0.29/kkg	3
Handling/ processing[a]		Particulates	Gas centrifuge	99.75	1		169

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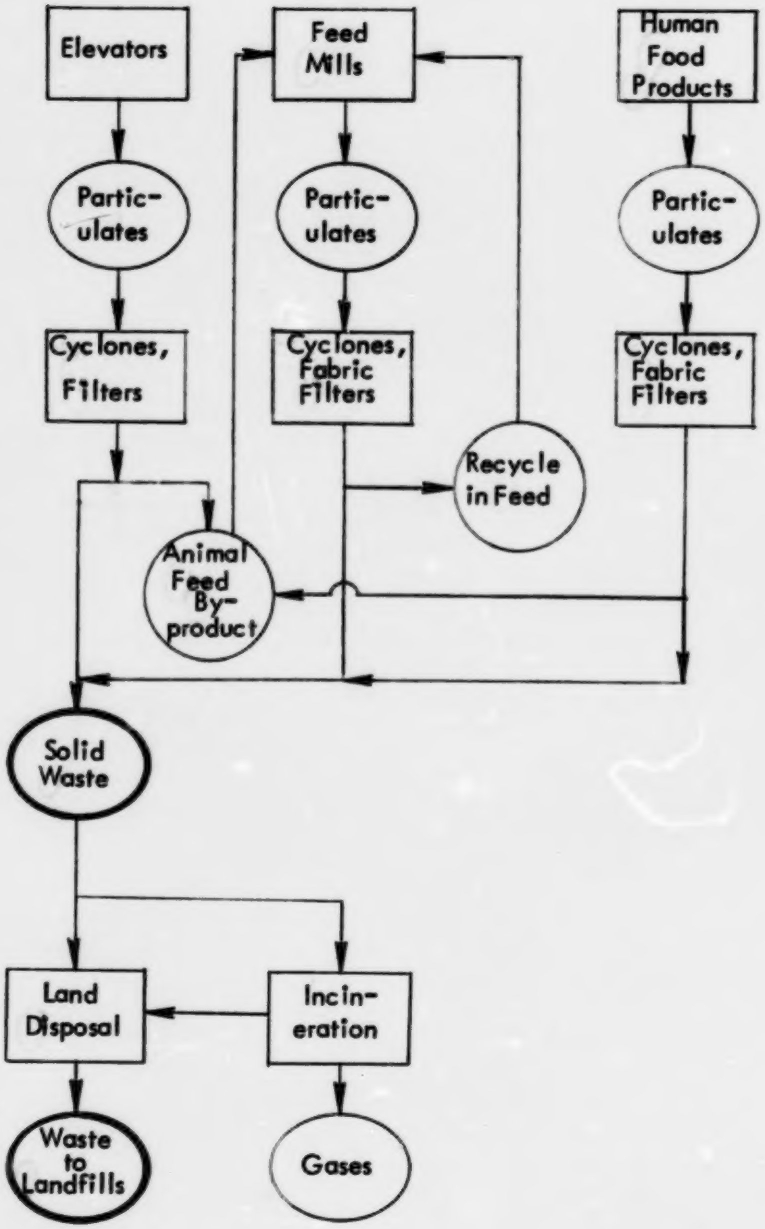
[a] Similar pollution controls are generally used at all steps in the grain processing cycle, and similar efficiencies are encountered for each treatment process at different steps.



Elevators
Feed Mills
Human Food Products
Partic-ulates
Partic-ulates
Partic-ulates
Cyclones, Filters
Cyclones, Fabric Filters
Cyclones, Fabric Filters
Recycle in Feed
Animal Feed By-product
Solid Waste
Land Disposal
Incin-eration
Waste to Landfills
Gases

FIGURE VIII - 2

AIR POLLUTION TREATMENT SCHEMATIC: GRAIN INDUSTRIES

VIII-12

more fines, however, will offset this so that reuse should remain at about 65 percent. Reuse data is currently quite poor for grain mill particulates, and consequently can be given a confidence level of 2, indicating a ± 50 percent possible variation. See Table VIII-6 for estimates.

Total Impact on Solid Waste Residues Produced by Pollution Treatment Methods.

The total weight of particulate-control derived solid waste will increase annually. Tables VIII-7 through VIII-10 contain forecast weights for 1971, 1975, 1980, and 1985. Increases are due to an average 3.5 percent increase in production and a higher capture ratio as fabric filters replace cyclones and are applied to uncontrolled mills. The reuse rate should increase and offset some of this increase in captured particles.

A constant increase in the use of fabric filters from less than 4 percent in 1970 to 99 percent in 1980 has been assumed. At the same time the proportion of cyclones can be expected to decrease. The use of gas centrifuges is an unknown factor; technology will be a major determinant in their amount of use by 1985. Residues are forecast to increase from 490 x 10^6 kg in 1971 to 1,150 x 10^6 kg in 1985.

Composition of Solid Waste Residues from Pollution Treatment Processes.

The particulates trapped during pollution control consist of grain fragments or vegetable matter commonly attached to grains. There are no special data available to estimate the parameters to characterize the solid waste residue particulates. Materials of similar composition (corn grain, corn stover, other grains) have approximately 1.3 to 5.1 percent ash at 10 percent moisture content.[150] Although compaction and diameter of particulates may change the volume significantly, the density of the residuals can be roughly estimated from the density of a common market bag of fine dry flour, 600 kg/m^3.[156] A heat content of approximately 4 kcal/gm for buckwheat hulls and various woody materials has been estimated;[432] this is probably a good approximation of the heat content of SIC 204 particulate residuals. Table VII-11 shows the estimated composition of solid waste generated from pollution control.

TABLE VIII-6
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 204

Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Particulates	Handling/processing	Cyclone	50-95	a	Dry particles
		Fabric filter	50-95	a	Dry particles
		Gas centrifuge	50-95	a	Particles

[a] In-house survey estimates.

TABLE VIII-7
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 204

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:	Handling/ processing	Cyclone	35	1,700	70	1,190	35	420
		Fabric filter	5	240	90	220	35	80
		Gas centrifuge	negl.	0				0
		None	60	0				0
		Total	100	1,940	73	1,410	35	500
Total Residues from Air Pollution Control:				1,940	73	1,410	35	500

TABLE VIII-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 204

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:	Handling/ processing	Cyclone	28	1,530	70	1,090	35	380
		Fabric filter	52	2,880	95	2,760	35	970
		Gas centrifuge	1	60	99.75	60	35	20
		None	19	0				0
		Total	100	4,470	88	3,910		1,370
Total Residues from Air Pollution Control:				4,470	88	3,910	35	1,370

TABLE VIII-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 204

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:	Handling/ processing	Cyclone	0	0	75	0	35	0
		Fabric filter	99	6,570	96	6,310	35	2,210
		Gas centrifuge	1	70	99.75	70	35	20
		None	0	0				0
		Total	100	6,640		6,380		2,230
Total Residues from Air Pollution Control:				6,640	96	6,380	35	2,230

TABLE VIII-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 204

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:	Handling/ processing	Cyclone	0	0	0			0
		Fabric filter	100	7,800	99	7,720	35	2,700
		Gas centrifuge	negl	0	80	0	35	0
		None	0	0	0			0
		Total	100	7,800		7,720		2,700
Total Residues from Air Pollution Control:				7,800	99	7,720	35	2,700

TABLE VIII-11

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 204

Item: Trapped Grain Particulates

Process or Activity: Air

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	1.0	See text
Volume	l -wet	1.7	
H_2O content (of wet weight)	%	9.1	
Combustible	kg	0.9	
Non-combustible	kg	0.03	
Ash content	kg	0.03	
Liquid form	kg		
Solid form	kg	1.0	
Energy content	kcal	4000.0	
Oxygen requirements	kg BOD_5		
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg		
Non-biodegradable	kg		

Factors Affecting Quality of Data.

The 1971 grain consumption figures from the U.S.D.A. are very accurate. The 3.5 percent average annual growth rate will likely continue to hold in the near future, but may change by the years 1980 and 1985. This estimate has been used to predict future consumption levels.

The pollution rates for grain processes are from an EPA report of early 1972. In some cases the pollution rates are after cyclone filtering. In these cases, values are multiplied by 3.33, using an average 70 percent efficiency for cyclones[10] in order to obtain the stated values.

The great bulk of the pollution is generated in grain elevators; only a few grain processes are performed in large enough scale to produce significant emissions.

The least accurate information concerns the predictions of future pollution controls. Only 40 percent of the grain industry was controlled in 1970 and most of the controls were cyclones. No data concerning applications of fabric filters were available. The E.P.A.[3] predicts 95 percent emission control effectiveness by 1977; this implies that 99 percent of grains will be processed under fabric filter pollution control. Thus a dramatic change in the grain industry is predicted as a result of the introduction of obligatory controls. The same source[3] provides three examples of fictitious plants with controls; investments for controls are 9 percent of total plant investment.

Reuse ratios of the captured particles are also uncertain. The high organic grain and plant content allows theoretically high reuse, up to 99 percent. But FDA regulations make reuse more difficult; this means costly storage and record-keeping. This sometimes eliminates reuse profitability. Thus present reuse is somewhere between 50 and 95 percent; new technology and larger plants should increase the profitability of reuse. Due to the low accuracy of reuse data for grain mills, the overall confidence level for predictions of solid residues generated from this sector should be given a confidence level of 2, indicating a ± 50 percent variation in the predictions.

Summary.

Untreated Discharges. Pollution contributed by the grain industries is almost exclusively particulates (plant and grain pieces) generated during handling and processing and then discharged to the air. The large majority of these particulates is generated during handling and processing in grain elevators. Total uncontrolled discharges of particulates were estimated to increase from 4.8 billion to 7.8 billion kg between 1971 and 1985.

Treatment Methods and Reuse. Three air pollution treatment methods--cyclones, fabric filters, and gas centrifuges--are used and will be used in the future to control particulate emissions from the grain industries. Gas centrifuging is the most efficient of the three, but fabric filters, intermediate of the three in efficiency, are forecast to become increasingly more common with time. Particulates are commonly reused for animal feed since they are actually pieces of grain; current reuse is in the range of 50 to 95 percent, and forecast to increase in the future.

Residues Generated from Pollution Control: Types and Amounts. Total residues from particulate control in the grain industry were forecast to increase from 490 million kg in 1971 to 1,150 million kg in 1985. The main factor responsible for this large increase is the increasing percentage of control forecast over time; while an estimated 60 percent of particulate emissions were uncontrolled in 1971, an estimated 100 percent control was forecast for 1985. The residues thus created will largely be pieces of grain, which are non-hazardous, non-toxic, and non-corrosive. Most of the residues will probably be continued to be reused for feed or other purposes so that only a small increment will be disposed as solid waste.

SECTION IX

PAPER AND ALLIED PRODUCTS
SIC 26

Introduction.

The Paper and Allied Products Industry converts wood and other cellulose materials into pulp and produces paper and allied products from pulp. The industry includes the following segments:

SIC 261 - Pulp Mills
SIC 262 - Paper Mills, Except Building Paper Mills
SIC 263 - Paperboard Mills
SIC 264 - Converted Paper and Paperboard Products, Except Containers and Boxes
SIC 265 - Paperboard Containers and Boxes
SIC 266 - Building Paper and Building Board Mills

The pulping process requires large quantities of water and is the major source of pollutants in the sector. Lignin, a by-product of pulping, is capable of producing large amounts of BOD_5, suspended solids and color units. Lignin is also burned in many plants to provide energy for the pulping process. This results in discharges of particulates, sulfur dioxide, hydrogen sulfide, and organic sulfides. Though discharge rates are relatively small, requiring a lower treatment level than is necessary in other industries, the large quantity of paper products produced results in a substantial amount of solid waste residues from pollution control.

Untreated Discharge Factors.

Air Pollutants. The main air pollutant discharge from the paper industry is particulates (see Table IX-1). High rates of particulate discharge are present during the pulping process, particularly from recovery boilers and direct contact evaporators, lime kilns, and calciners. The latter two pieces of equipment are used to produce and recover kraft liquor. Smaller quantities of hydrogen sulfide, organic sulfides, and mercaptans are also discharged to the air during pulping. The discharge rates in Table IX-1 were available only for sulfate and sulfite pulping.

Water Pollutants. The discharges prior to treatment for water pollutants are presented in Table IX-2. Water pollutants are limited to suspended solids, BOD_5 and color because these are the three results of lignin presence in the water. Techniques for removing lignin will also remove the small amounts of other water pollutants. The major solid waste residue created will be due to the lignin removal. Liquor recovery is an inherent aspect of the process. Pulping liquors have, therefore, not been considered a source of separate discharge. The references used to determine the discharge factors in Table IX-1 and IX-2 were generally complete, resulting in a confidence level of 4 for the tables, indicating a possible variation of 10 percent in the data.

TABLE IX -1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Pulping-sulfate	Blowtank accumulators	kkg	H_2S	0.05	169
			Organic sulfides, mercaptans	1.5	
	Washers and screen		H_2S	0.01	
			Organic sulfides, mercaptans	0.1	
	Multiple-effect evaporators		H_2S	0.25	
			Organic sulfides, mercaptans	0.2	
	Recovery boilers, direct contact evaporators		Particulates	75.5	
			SO_2	2.5	
			H_2S	6.0	
			Organic sulfides, mercaptans	0.45	
	Smelt dissolving tank		Particulates	1.0	
			H_2S	0.015	
			Organic sulfides, mercaptans	0.02	
	Lime kilns		Particulates	22.5	
			H_2S	0.5	
			Organic sulfides, mercaptans	0.3	
	Condenser turpentine		H_2S	0.005	
			Organic sulfides, mercaptans	0.25	
	Fluidized-bed calciner		Particulates	36.0	
	Paper board		Particulates	Negligible	
	Fiberboard		Particulates	0.3	

TABLE IX-1 (Cont.)
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Pulping-sulfite	Absorption	kkg	SO_2	0.065-4.65	277
	Digester relief			0.48	
	Digester blow			0.178	
	Evaporation			22.4	
	Furnace			n.d.	
Pulping-neutral	n.d.				

[a] For 1971 or most recent available information.

[b] n.d. - no data available.

TABLE IX-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Old Technology[a]					
Wood preparation	Debasker, chipper	kkg product	SS	20	97
Deinking				42 - 630	
Pulping	Mechanical			15	
	Sulfate			14	
	Sulfite			38	
Pulp screening	Mechanical			n.d.[d]	
	Sulfate			5	
	Sulfite			7	
Pulp washing	Mechanical			n.d.	
	Sulfate			4	
	Sulfite			13	
Pulp thickening	Mechanical			7	
	Sulfate			5	
	Sulfite			2	
Bleaching	Mechanical			n.a.	
	Sulfate			n.a.	
	Sulfite			15	
Paper making	General			30	
Old technology			BOD_5	100	
Present (1963) Technology					
Wood preparation		kkg product	SS	5	
Deinking				n.d.	

TABLE IX-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Pulping	Mechanical	kkg product	SS	n.d.	97
	Sulfate			9	
	Sulfite			15	
Pulp screening	Mechanical			n.d	
	Sulfate			2	
	Sulfite			4	
Pulp washing and thickening	Mechanical (no washing)			6	
	Sulfate			8	
	Sulfite			4	
Bleaching	Mechanical			n.d.	
	Sulfate			30	
	Sulfite			8	
Paper making	General			23	
Present technology			BOD_5	66	
New (1968) Technology[c]					
Wood preparation		kkg product	SS	5	
Pulping	Mechanical			n.d.	
	Sulfate			9	
	Sufite			15	
Deinking				n.d.	
Pulp screening	Mechanical			n.d.	
	Sulfate			2	
	Sulfite			4	

TABLE IX-2 (Cont.)
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Pulp washing and thickening	Mechanical	kkg product	SS	6	97
	Sulfate			8	
	Sulfite			4	
Newer technology			BOD_5	40	
Pulping	Sulfate or sulfite		Color	100	293
Bleaching	Sulfate or sulfite		Color	120	293

---

[a] Old technology is the industrial plant processes and equipment prevalent prior to 1963.

[b] Present technology is the industrial plant processes and equipment prevalent in pulp and paper plants in 1963.

[c] New technology is the industrial plant processes and equipment being put into pulp and paper plants built during 1968 and thereafter.

[d] n.d. - no data available.

Industry Description and Schematic.

The Paper and Allied Products Industry receives as raw materials substances high in cellulose. Timber is the main raw material, received in the form of logs. Waste paper, after any necessary deinking, is fed into a slurry. Rags may also be fed into the process in a similar manner. The primary product of the industry is pulp, from which the various paper products are then produced. The production of pulp creates virtually all of the pollutants connected with the paper industry. The present analysis will, therefore, concentrate on the pulp producing process.

The received logs must first be debarked through mechanical, chemical, or hydraulic means. The removed bark is a waste product, although it is sometimes burned as fuel for the pulping process or otherwise disposed of. The debarked logs are then converted to chips and fed to the pulping process. Pulping may be performed by either mechanical or chemical means. Mechanical pulping, currently used in 25 percent of the plants, is comparatively pollution-free. The chemical process, on the other hand, involves the use of a solution of sodium hydroxide and sodium sulfide, called kraft liquor. Cooking the woodchips in this liquor results in a separation of lignin and cellulose. The cellulose is combined with the cellulose obtained from waste paper and rags, resulting in the cellulose slurry known as pulp. Lignin is burned in a recovery boiler to produce heat for the pulping process. The pulp is washed and cleaned in either a diffuser or a rotary drum vacuum filter (sometimes called a blow tank). The chemicals used to produce the kraft liquor are then recovered. A newer technology, known as sulfite pulping, uses a cheaper pulping liquor (sodium sulfite) which is sometimes incinerated because it is not sufficiently valuable to make recovery worthwhile. This incineration may cause a major air pollution from sulfur dioxide and particulates. Sulfite pulping is presently used in less than 10 percent of the industry, and it is assumed that stricter emission guidelines will eventually cause chemical recovery of the liquor to become a common practice in this sector of the industry.

Once the pulp has been washed, it is dewatered for thickening and bleached for whitening. The water removed during these two steps has high levels of suspended solids, BOD_5 and color. The next step is to produce final products from the pulp. A schematic of the process described above is presented in Figure IX-1.

Economic Forecasts.

The paper and allied products market has historically been typified by cyclical growth and overproduction. Growth has recently begun to be channeled into cost-effective improvements, such as computerized controls, or into related industries, such as real estate and lumber. This has resulted in a closer relationship between supply and demand, which is expected to continue.

The demand for paper products usually follows the general indicators of economic activity, such as unemployment and disposable real income. Competition from the plastic container, aluminum foil, and folding carton industries is forecast to continue

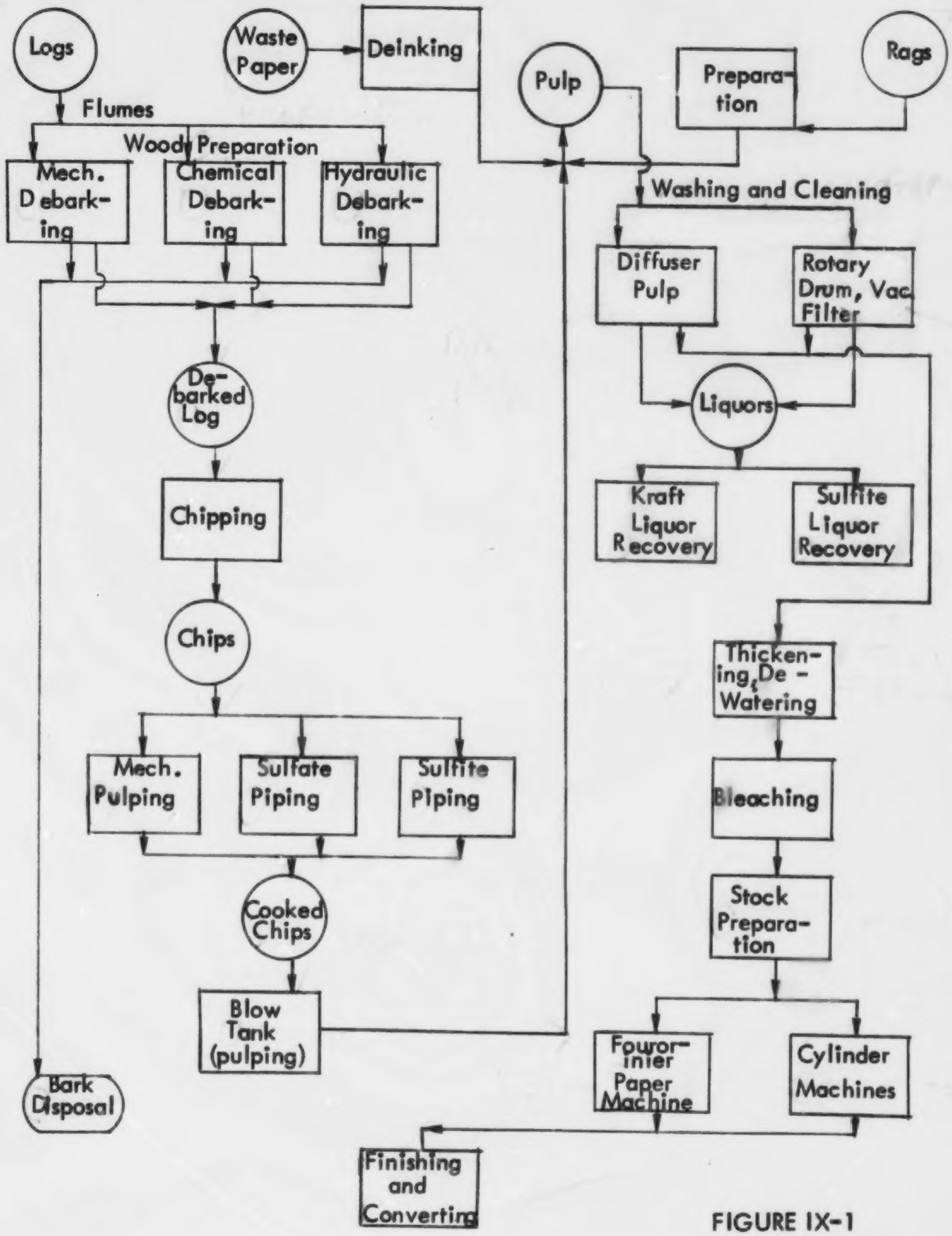

Logs
Waste Paper
Deinking
Pulp
Preparation
Rags
Flumes
Wood Preparation
Mech. Debarking
Chemical Debarking
Hydraulic Debarking
Washing and Cleaning
Diffuser Pulp
Rotary Drum, Vac. Filter
Liquors
Kraft Liquor Recovery
Sulfite Liquor Recovery
De-barked Log
Chipping
Chips
Thickening, De-Watering
Bleaching
Mech. Pulping
Sulfate Piping
Sulfite Piping
Cooked Chips
Stock Preparation
Blow Tank (pulping)
Fourorinier Paper Machine
Cylinder Machines
Bark Disposal
Finishing and Converting

FIGURE IX-1

INDUSTRY SCHEMATIC:
PULP AND PAPER MILLS
OVERVIEW

at the present level.

Based on the above-mentioned assumptions and the forecast data presented in Table IX-3, production in the industry through 1985 is expected to follow the predictions presented in Table IX-4. Total paper and paperboard production is forecast to increase from 50.2 million kkg to 88.6 million kkg between 1971 and 1985. A three-percent growth rate was used for sulfate pulping (kraft pulping) and a two-and-a-half-percent growth rate was used for mechanical pulping. Sulfite pulping is predicted to remain constant as emissions guidelines render it less desirable. Table IX-4 has been given a confidence level of 3, indicating a possible 25 percent variance in the data, due to the compounded uncertainty of the many assumptions required to arrive at the forecasts.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table IX-5 presents an inventory of discharges capable of producing solid waste residues when treated. The table is calculated using the water discharge factors for new technology in Table IX-2. New technology is equivalent to the technology prevalent in 1968. Both air and water pollutant discharges are inventoried. The discharge of BOD_5 has been considered for the overall process. The production of fiberboard can be seen to be the only final product process which contributes substantially to pollutant discharge. The discharge inventory for this sector, based on the product of discharge rates and economic forecasts, can be given a confidence level of 3, indicating a possible 25 percent variation in the data.

Likely Pollution Treatment Processes.

Air Pollution Control. Scrubbers currently bear the brunt of the air pollution control responsibility in the paper industry. The electrostatic precipitator, which can be operated on a dry basis, may become more popular as water effluent guidelines become more severe. The Environmental Protection Agency does not foresee the necessity of air pollution control other than the control of particulates and sulphides.
Figure IX-2 illustrates air pollution treatment processes. Where scrubbers are used, the SS created are fed to the water pollution control system.

Water Pollution Control. Table IX-6 presents the likely treatment processes for water pollution control. Many of the treatment processes presented are actually designed to lessen the pollutant loading of the water before it undergoes final treatment; these are referred to as process modifications. The final treatment process used is one of the processes listed at the end of the table under wastewater treatment. One of these final processes must be used regardless of the combination of preliminary processes.

For color removal, activated carbon adsorption is the most common treatment process. The ratio of dry residue weight to dry weight of pollutant removed is about 1.5. This calculation was based on the amount of activated carbon required to treat the wastewater of a plant with a capacity of 453.6 metric tons per day. A 15.1 million

TABLE IX-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 26

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Paper and paper-board	Production	10^6 kkg			49.3	61.0	73.9	88.6	208	1971
			74	58.0					212	1973
			73	56.7	49.9	61.0	73.3	87.3	127	1973
					50.0			88.6	209	1973
	Capacity (planned)		74	58.2					209	
	Capacity (required)		76	66.0					209	
Pulpwood	Production	10^6 kkg	73	4 .6	39.8	48.2	57.4	67.2	127	1973
	Sulfate pulping (production)		72	28.4	26.9				209	
	Sulfate pulping (demand)		70	27.7	n.a.	34.5	43.4	n.a.	210	1967
	Sulfite pulping (production)		72	3.4	3.4				209	1973
Paper and pulp	All production	10^6 kkg			49.3	61.0	73.9	88.6	208	1971
			72	52.8					83	1973
			74	58.1					212	1973
	Sulfate pulping (production)		77	30.6	31.5				89	1972
	Sulfate pulping (demand)		70	27.3		34.5	43.4		210	1967

TABLE IX-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 26

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Paper and pulp	Sulfite pulping–capacity	10^6 kkg	72	3.0					211	1973
	Sulfite pulping–demand		70	3.0		3.2	3.4		210	1967
	Groundwood pulp–demand		70	4.4		5.2	6.1		210	1967

TABLE IX-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 26

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Total production-paper and paper board		10^6 kkg	50.2	68	61.0	68	73.3	68	88.6	68
Pulping	Totals	10^6 kkg	39.8	209	48.2	68	57.4	68	67.2	68
	Sulfate		26.8		30.2	a	35.0	a	40.8	a
	Sulfite		3.4		3.6	b	3.6	b	3.6	b
	Groundwood mechanical		4.1		4.5	c	5.1	c	5.7	c
	Other non-mechanical		2.1		n.d.		n.d.		n.d.	

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[a] Extrapolated from base year at 3-percent per year compound growth rate.

[b] No growth forecast because of pollution control requirements.

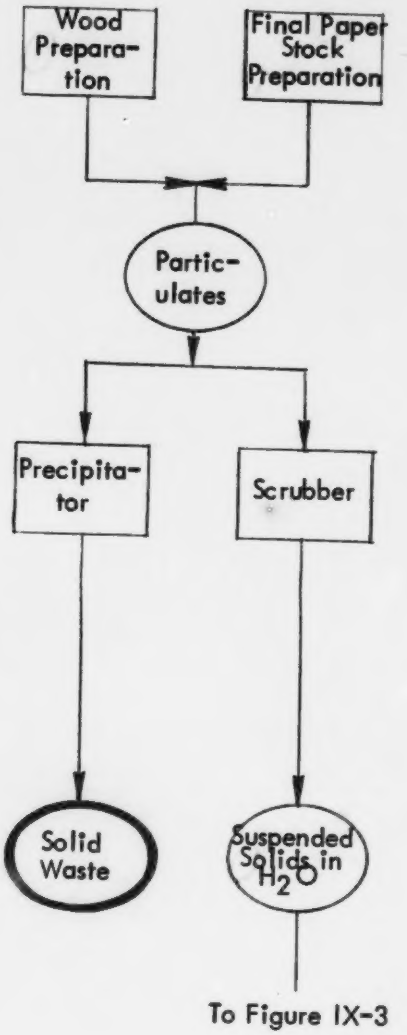
[c] Extrapolated from base year at 2.5% per year compound growth rate.

TABLE IX-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged 1971	1975	1980	1985
WATER POLLUTANTS						
Suspended Solids:	Wood prep.	97	251	305	367	443
	Pulping-sulfate		241	272	315	367
	-sulfite		52	54	54	54
	Pulp screen-sulfate		54	61	70	82
	-sulfite		14	14	14	15
	Pulp wash, thicken -mech.		24	27	31	34
	-sulfate		214	241	280	327
	-sulfite		14	15	15	15
	Total SS-sum		864	989	1,146	1,237
Color:	Bleaching, pulping	293	8,681	10,599	12,635	14,791
BOD_5:	Total	97	2,007	2,440	2,932	3,546
AIR POLLUTANTS						
H_2S:	Chem. pulping-tank	169	2.0	2.4	2.9	3.4
	-washers		0.4	0.5	0.5	0.6
	-evaporators		10.0	12.0	15.0	17.0

TABLE IX-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 26

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
H_2S (cont.)	Recovery boiler	169	239	289	345	403
	Smelt dissolving tank		0.6	0.7	0.8	1.0
	Lime kilns		20	24	29	34
	Turpentine condenser		0.2	0.3	0.3	0.4
Organic sulfides and mercaptans	Blow tank	169	60	73	86	101
	Washers		4	5	6	7
	Evaporators		8	10	12	14
	Smelt diss. tank		0.8	1.0	1.2	1.4
	Recovery boiler		18	22	26	30
	Lime kilns		12	15	17	20
	Turpentine condenser		10	12	15	17
Particulates	Recovery boiler	169	3,007	3,637	4,336	5,076
	Smelt dissolving tank		40	48	57	67
	Lime kilns		896	1,084	1,292	1,512
	Calciner		1,433	1,735	2,068	2,420
	Total Particulates:		5,376	6,504	7,753	9,073



Wood Preparation
Final Paper Stock Preparation
Particulates
Precipitator
Scrubber
Solid Waste
Suspended Solids in H2O
To Figure IX-3

FIGURE IX-2

AIR POLLUTION TREATMENT SCHEMATIC:
PULP AND PAPER MILLS

TABLE IX-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 26

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Waste-reducing process modifications:							
Wood preparation		SS	With water reuse	77	1		97
			Long log preparation	95	1		
Pulping	Mechanical	SS	With water reuse	n.d.	n.d.		97
			Refining	46	1		
	Sulfate		Batch with water reuse	37	1		
			Continuous	89			
	Sulfite		Calcium base with water reuse	24	1		
			Soluble bases with liquor recovery	79	1		
Pulp screening	Sulfate	SS	With partial water reuse	55	1		97
			Screening and cleaning with water reuse	100	1		

TABLE IX-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 26

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Pulp screening (Cont.)	Sulfite	SS	With partial water reuse	43	1		97
			Screening & cleaning with water reuse	100	1		
Other water treatments:							
Pulping	Recovery boilers, direct contact evaporators	Particulates	Electrostatic precipitator	90	1		169
			Venturi scrubber	70	1		169
	Lime kiln		Scrubber	95	1		277
Pulp washing and thickening	Mechanical	SS	Thickening with vacuum filtration	21	1		97
			Thickening and cleaning with vacuum filtration	57	1		
	Sulfate		Vacuum filter	17	1		
	Sulfite		Vacuum filter	72	1		
			Multistage vacuum filter	79	1		
	All	Color	Adsorption	90	1.5		
			Lime coagulation	85	1.1		

TABLE IX -6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 26

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Bleaching	Sulfate	SS		n.d.[a]			97
	Sulfite	SS	With low water reuse	50	1.0		
			With high water reuse	80	1.0		
	All	Color	Adsorption	90	1.5		
			Lime coagulation	85	1.1		
Paper making		SS	White water recovery	35	1.0		97
			With improved white water recovery	50	1.0		
All wastewater producing steps	Primary treatments	SS	Flocculation				191
			Sedimentation basin				
			Gravity clarifier	70-90			
		Settleable solids	Gravity clarifier	>95			
	Secondary treatments	SS	Oxidation pond				120
			Trickling filter				
			Aerated lagoon				
			Activated sludge		0.35-0.55 lb sludge per lb BOD_5 removed		
			Irrigation				

TABLE IX-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
	Secondary treatments (Cont.)	BOD_5	Mechanically aerated basin	75-94	< 0.1		97
			Trickling filters				
			Activated sludge	85	1.3		274
			Coagulation	75	1.1		
			Oxidation basin	80	0.5		

[a] No data available.

liter per day wastewater flow was determined for such a plant. A 90 kilogram loading of color units per ton of product was assumed. Based on these assumptions, 1.5 kilograms per day of exhausted adsorption media would be produced for each kilogram of color unit removed. Although most of the activated carbon is regenerated, the exhausted carbon is a potential solid waste residue. Lime coagulation is the other alternative for color removal. A similar calculation resulted in a ratio of residue to pollutant removed of 1.1 for lime coagulation. This technology has been applied in the industry on an experimental basis and is currently being evaluated. Lime coagulation is a less expensive process for the paper industry in terms of lime consumed (in processing spent pulping liquors) and handling costs.

Figure IX-3 identifies the principal water pollution treatment processes for the industry. Primary treatments (physical removal devices) generally control suspended solids efficiently; secondary (normally biological) treatment processes are needed to control BOD_5. A detailed schematic of the lime coagulation process for color control is presented in Figure IX-4.

Reuse Potential for Solid Residues Produced by Pollution Treatment Processes.

Several alternative disposal techniques exist for solid residues generated by air and water pollution control. Sludge may be handled in slurry form and pumped to landfills, or it may be dewatered and handled in a semi-dry state. Dewatered sludge is sometimes incinerated. Biological digestion of the sludge is also possible and may reduce the volume by as much as 50 percent. Some sludges may be spread on land. In the past, however, the usual practice has been to landfill the sludges, perhaps after lagooning or sludge digestion.[97] Increased land costs, reduced land availability, and more stringent regulations have encouraged incineration, but air pollution control laws have banned incineration in many cities.

Future by-product development areas that may partially offset treatment costs and reduce landfill disposal treatment costs are: 1) fiber recovery from primary sludge for use in the building materials industry; 2) drying activated sludge for use as fuel; and 3) processing activated sludge as an animal food supplement or commercial fertilizer.[97] The eventual success of these alternatives is doubtful and no detailed breakdown of disposal techniques can be made. For that reason the reuse percentages shown in Table IX-7 are rough estimates. The estimates for primary and secondary treatment of suspended solids are estimates of reuse combined with an estimate of the mass reduction due to digestion or incineration.

Total Impact on Solid Waste of Pollution Treatment Processes.

Tables IX-8 through IX-11 present the solid waste produced by pollution treatments in pulp and paper mills. The forecasts in these tables show a large, steady increase in total weight produced over time, with a fairly constant waste composition. The largest part of solid waste is due to color treatment by carbon adsorption. The resulting waste is a mixture of what was originally suspended

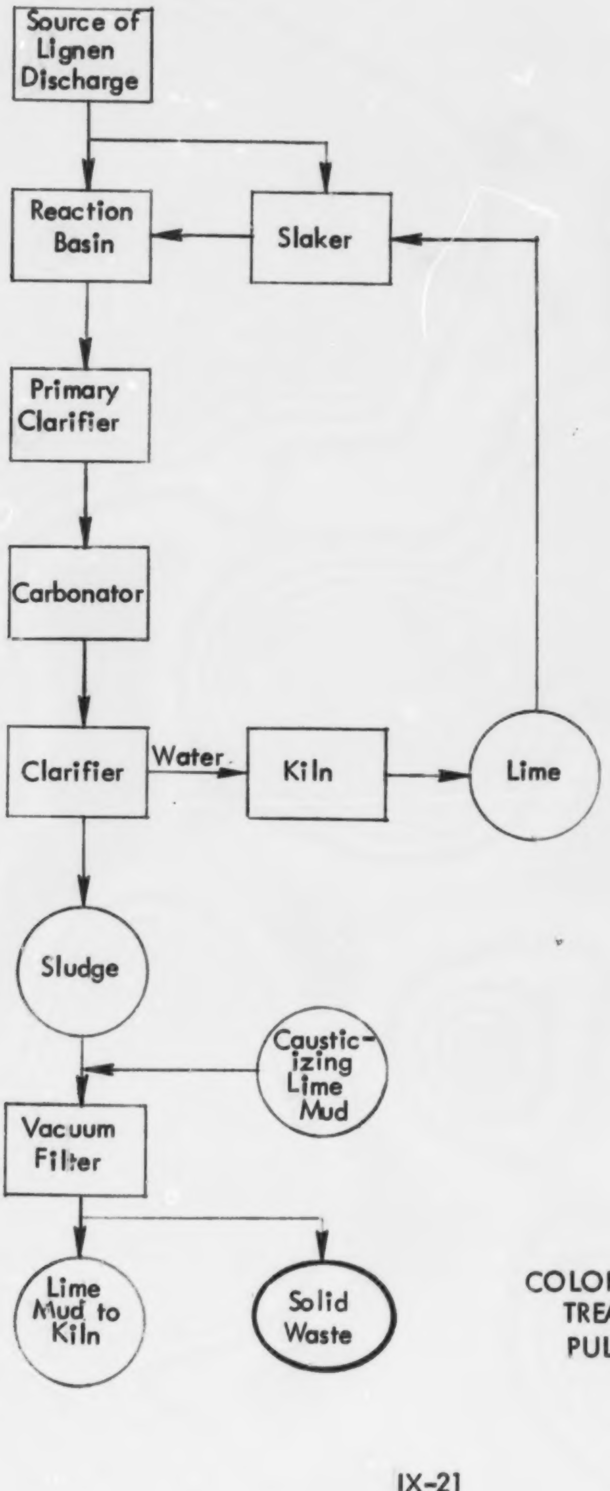

Source of Lignen Discharge
Reaction Basin
Slaker
Primary Clarifier
Carbonator
Clarifier
Water
Kiln
Lime
Sludge
Causticizing Lime Mud
Vacuum Filter
Lime Mud to Kiln
Solid Waste

FIGURE IX-3

COLOR (LIGNEN) POLLUTION
TREATMENT SCHEMATIC:
PULP AND PAPER MILLS

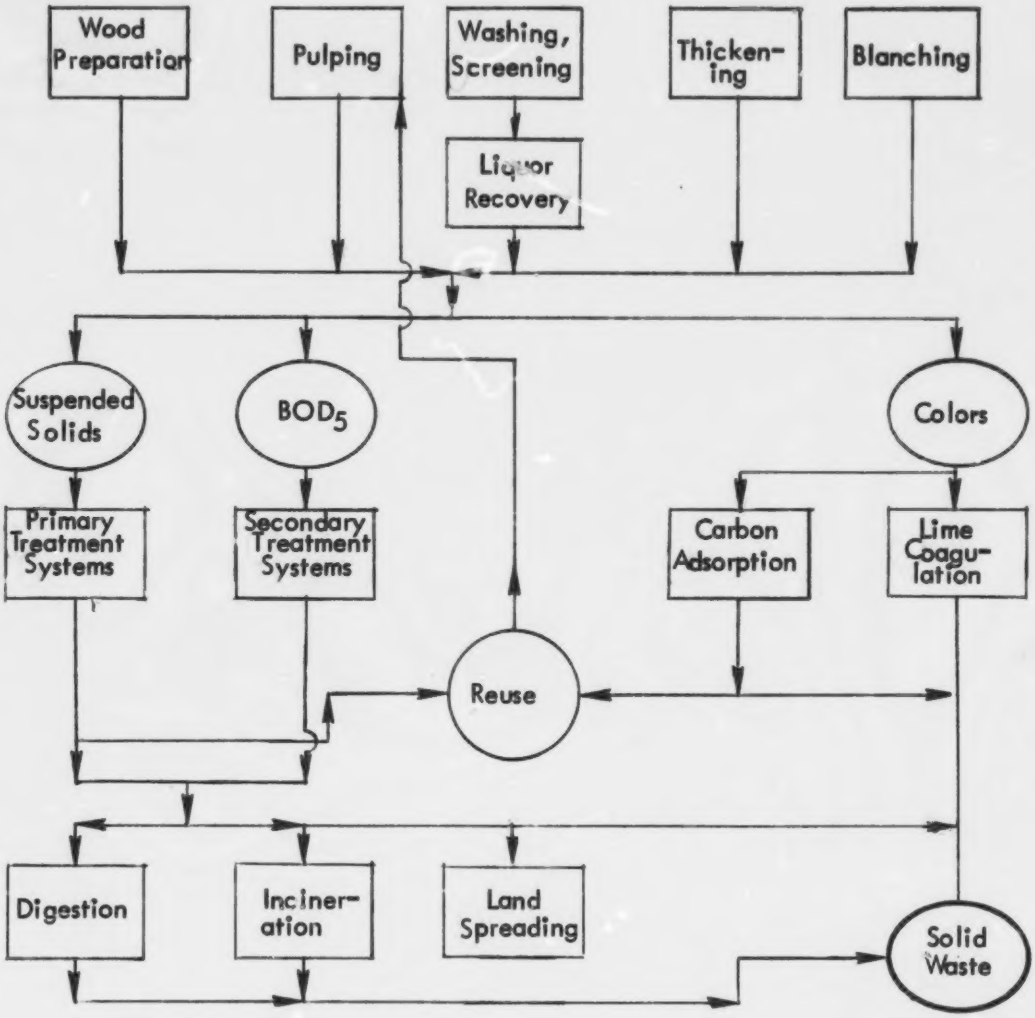

Wood Preparation
Pulping
Washing, Screening
Liquor Recovery
Thickening
Blanching
Suspended Solids
BOD5
Colors
Primary Treatment Systems
Secondary Treatment Systems
Carbon Adsorption
Lime Coagulation
Reuse
Digestion
Incineration
Land Spreading
Solid Waste

FIGURE IX-4

WATER POLLUTION TREATMENT SCHEMATIC:
PULP AND PAPER MILLS

TABLE IX-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 26

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Wood preparation -suspended solids		Screening	0	97	Bark, chips, non-usable wastes.
Other steps -suspended solids		Screening and reuse	100[a]		Reuse as pulp.
		Sedimentation	55[a]		Some residues contaminated with liquors.
		Flotation	55[a]		Some residues contaminated with liquors.
		Mechanical clarifier	55[a]		Some residues contaminated with liquors.
All processes -BOD_5		Coagulation	20	274	Non-usable residues; may be digested for reduction in mass.
		Oxidation basin	20		Non-usable residues; may be digested for reduction in mass.
		Aeration	20		Non-usable residues; may be digested for reduction in mass.
		Activated sludge	20		Non-usable residues; may be digested for reduction in mass.
Pulping and bleaching -color		Carbon adsorption	70		Regeneration of activated carbon except that which is spent.
		Lime coagulation	0		Lime mud.

[a] Estimate includes mass reduction due to digestion and incineration.

TABLE IX-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 26

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:		Precipitator	30	1,610	90	1,450	100	1,450
All sources		Wet scrubber	70	(3,760)[a]	70	(2,634)to SS water treatment		
		Total	100	(5,380)	76	(4,090)	100	(4,090)
Total Residues from Air Pollution Control				1,610	90	1,450	100	1,450
WATER POLLUTANTS								
Suspended solids:		Primary treatment:						
Wood preparation		Screening	100	250	70	180	100	180
All other steps		Screening & reuse	10	330	70	230	0	0
		Sedimentation	55	1,800	85	1,530	45	690
		Flotation	25	820	80	660	45	300
		Mechanical clarifier	10	330	95	310	45	140
		Total	100	3,530	82	2,900	45	1,300

TABLE IX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 26

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
BOD_5:								
All steps		Secondary treatment:						
		Coagulation	20	440	75	330	80	260
		Oxidation basin	20	200	80	160	80	130
		Aeration	40	160	85	140	80	110
		Activated sludge	20	520	85	440	80	350
		Total	100	1,320	81	1,070	80	860
Color:								
Pulping & bleaching		Carbon adsorption	80	6,900	90	6,210	30	1,860
		Lime coagulation	20	1,700	85	1,440	100	1,440
		Total	100	8,600	89	7,660	43	3,310
Total Residues from Water Pollution Control:				13,450	86	11,630	47	5,460
Total Residues from Air and Water Pollution Control:				15,063	87	13,080	53	6,910

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[a] Residues created during scrubbing are transferred to water as suspended solids, where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid wastes appears in the water pollutant estimates, since no solid wastes are created until water treatment occurs following intermedial transfer.

TABLE IX-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 26

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:		Precipitator	40	2,600	90	2,340	100	2,340
All sources		Wet scrubber	60	(3,900)[a]	70	(2,030) to SS water treatment		
		Total	100	6,504	67	4,370	100	(4,370)
Total Residues from Air Pollution Control				2,600	90	2,340	100	2,340
WATER POLLUTANTS								
Suspended solids:		Primary treatment:						
Wood preparation		Screening	100	300	70	210	100	210
All other steps		Screening & reuse	15	510	70	360	0	0
		Sedimentation	45	1,540	85	1,310	45	590
		Flotation	10	340	80	270	45	120
		Mechanical clarifier	30	1,020	95	970	45	440
		Total	100	3,710	84	3,120	44	1,360
BOD_5:		Secondary treatment:						
All steps		Coagulation	15	400	75	300	80	240
		Oxidation basin	20	240	80	190	80	150
		Aeration	30	150	85	130	80	100
		Activated sludge	35	1,110	85	940	80	760
		Total	100	1,900	82	1,560	80	1,250

TABLE IX-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 26

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Color:								
Pulping & bleaching		Carbon adsorption	75	7,900	90	7,110	30	2,130
		Lime coagulation	25	2,600	85	2,210	100	2,210
		Total	100	10,500	89	9,320	47	4,340
Total Residues from Water Pollution Control:				16,110	87	14,000	50	6,950
Total Residues from Air and Water Pollution Control:				18,712	87	16,340	57	9,290

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[a] See footnote (a), Table IX-8.

TABLE IX-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 26

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:		Precipitator	50	3,880	90	3,490	100	3,490
All sources		Wet scrubber	50	(3,880)[a]	70	(2,710) to SS	water	treatment
		Total	100	7,760	80	6,200	100	(6,200)
Total Residues from Air Pollution Control:				3,880	90	3,500	100	3,490
WATER POLLUTANTS								
Suspended solids:		Primary treatment:						
Wood preparation		Screening	100	370	70	260	100	260
All other steps		Screening & reuse	20	700	70	490	0	0
		Sedimentation	15	530	85	450	40	180
		Flotation	5	180	80	140	40	60
		Mechanical clarifier	60	2,100	95	2,000	40	790
		Total	100	3,880	86	3,340	39	1,300
BOD_5:		Secondary treatment:						
All steps		Coagulation	10	320	75	240	70	170
		Oxidation basin	15	220	80	180	70	120
		Aeration	25	150	85	130	70	90
		Activated sludge	50	1,900	85	1,620	50	810
		Total	100	2,590	83	2,160	55	1,190

TABLE IX-10 (Cont.)

TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 26

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Color:								
Pulping & bleaching		Carbon adsorption	70	8,800	90	7,920	30	2,380
		Lime coagulation	30	3,700	85	3,140	100	3,140
		Total	100	12,500	88	11,060	50	5,520
Total Residues from Water Pollution Control:				18,970	87	16,560	48	8,000
Total Residues from Air and Water Pollution Control:				22,846	88	20,050	57	11,490

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[a] See footnote (a), Table IX-8.

TABLE IX-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 26

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:		Precipitator	60	5,450	90	4,900	100	4,900
All sources		Wet scrubber	40	(3,630)[a]	70	(2,540) to SS water treatment		
		Total	100	(9,080)	82	(2,440)	100	(7,440)
Total Residues from Air Pollution Control:				5,450	90	4,900	100	4,900
WATER POLLUTANTS								
Suspended solids:		Primary treatment:						
Wood preparation		Screening	100	440	70	310	100	310
All other uses		Screening & reuse	20	690	70	480	0	0
		Sedimentation	5	170	85	149	35	50
		Flotation	5	170	80	140	35	50
		Mechanical clarifier	70	2,400	95	2,280	35	800
		Total		3,870	87	3,350	36	1,210
BOD_5:		Secondary treatment:						
All steps		Coagulation	5	190	75	140	60	90
		Oxidation basin	15	270	80	220	60	130
		Aeration	5	40	85	30	60	20
		Activated sludge	75	3,500	90	3,150	50	1,580
		Total	100	4,000	88	3,540	51	1,820

TABLE IX-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 26

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Color:								
Pulping & bleaching		Carbon adsorption	60	8,900	90	8,010	30	2,400
		Lime coagulation	40	5,900	85	5,020	100	5,020
		Total	100	14,800	88	13,020	57	7,420
Total Residues from Water Pollution Control:				22,670	88	19,920	52	10,450
Total Residues from Air and Water Pollution Control:				28,116	88	24,820	62	15,350

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[a] See footnote (a), Table IX-8.

solids and carbon or lime (depending on the filtering method). Much of the solid waste will be handled like ordinary sludge. Total residues from pollution control in this sector are forecast to increase from 7,220 x 10^6 kg to 15,220 x 10^6 kg between 1971 and 1985. The forecast data may be given a confidence level of 3, indicating a ± 25 percent possible variation.

Factors Affecting Quality of the Data.

Detailed information was available on most aspects of the paper industry. This industry was one of the first to be criticized by environmentalists. As a result, the detailed pollution emission data necessary for estimation of solid waste impacts were available. Economic forecasts from different sources are similar; this builds confidence in the forecasted production values. The industry's methods are advancing slowly with EPA regulations guiding changes in its methods. Finally, the effect on generated solid waste of new technology will be minimal. These factors build confidence in the present estimates. Throughout this Section confidence levels of 4 and 3 (with 3 for the predicted values in 1980 and 1985) have been established. An overall confidence level of 3 (indicating a possible 25 percent variation) is justifiable, based on the stability of the values. The potential for significantly higher solid waste generation is low, due to the high effectiveness of current methods. Conversely, the reuse potential of the solid waste not currently reused is negligible.

Summary.

Untreated Discharges. The majority of pollutants from the paper industry derives from some aspect of the pulping process. Suspended solids are discharged to water in significant quantities during wood preparation and pulping. BOD_5 is discharged primarily during pulp washing and dewatering, and large amounts of color are discharged during bleaching and pulping. Major pollutants discharged by the paper industry are: hydrogen sulfide, mostly from recovery boilers; organic sulfides and mercaptans, mostly from blowtanks, recovery boilers, lime kilns, and turpentine condensers; particulates, mostly during calcining and from recovery boilers; and sulfur dioxide, mostly from boilers and direct-contact evaporators. Uncontrolled discharges of the aforementioned pollutants in 1971 and 1985, respectively, are forecast to be: suspended solids - 945 and 1,387 million kg; BOD_5 - 2.0 and 3.5 billion kg; color - 8.7 and 14.8 billion kg; hydrogen sulfide - 272 and 460 million kg; organic sulfides and mercaptans - 113 and 189 million kg; particulates - 5.4 and 9.5 billion kg; and sulfur dioxide - 100 and 168 million kg.

Treatment Processes and Reuse. Precipitators and scrubbers are the main treatment methods for controlling all air pollutant discharges in the paper industry, and produce notable quantities of solid waste. Many newer industrial technologies will lessen the water pollutant load before paper plant effluents receive wastewater treatment. Thickening and filtration are used to control suspended solids during pulping, washing and thickening; color is controlled, during the same steps, by adsorption and lime coagulation. Water reuse is effective in reducing pollutant load prior to treatment, and is forecast to increase in the future. Primary wastewater treatments (screening, sedimentation, flotation, and clarification) and, to a lesser extent, secondary treatments (coagulation, oxidation, aeration, and activated sludge) produce solid waste residues in the control of suspended solids and BOD_5. Reuse alternatives are mainly fiber recovery from primary sludge and use of activated sludge as fuel, animal food supplements, or fertilizer.

Residues Generated from Pollution Control. Over the period 1971 to 1985, solid waste residues from air pollution control are forecast to increase from 1,450 to 4,900 million kg. Over the same period, solid waste residues from water pollution control are forecast to increase from 5,460 to 10,450 million kg. Consequently, residues from both sources are forecast to increase from 6,910 to 15,350 million kg.

SECTION X
CHEMICALS AND ALLIED PRODUCTS
SIC 28

Introduction.

The Chemicals and Allied Products Industry is a significant contributor to National water pollutant discharges. Some air pollutants are generated by this industry, although their total weight is not a very large percentage of National emissions before treatment. This industry is a complex one, in terms of evaluating pollutant discharges and solid waste impacts of air and water pollution control, because of the large number of products and manufacturing processes involved, and because of the many forms the pollutant discharges may take. This industry includes the following sub-sectors:

SIC	Description
281	Industrial Inorganic Chemicals
282	Plastics and Synthetic Resins
286	Industrial Organic Chemicals
287	Agricultural Chemicals
2895	Carbon Black

Soaps and Detergents (SIC 284) and Paints and Varnishes (SIC 285) are not included in the present analysis. While many of the air pollutants produced by these sectors may be recycled in the product (as for SO_x emissions from sulfuric acid manufacture), most sludges from water pollution control will be incinerated or disposed to landfills (usually Class I because of the dangerous nature of many of the substances involved).

Untreated Discharge Factors.

Air Pollutants. Production processes in the industrial inorganic chemicals segment of the chemicals industry generate a large array of air pollutants. However, among the significant emissions of air pollutants, only fluorides and particulates from the manufacture of phosphoric acid, and particulates and sulfur oxides from the manufacture of sulfuric acid are considered capable of producing significant amounts of solid waste residues when treated. Table X-1 lists untreated discharge factors for relevant polluting processes in chemicals manufacture. Air pollutants not included in the table, such as chlorine, ammonia, hydrogen chloride and nitric oxides, are either recovered or produced as by-products of specific chemical manufacturing processes, and result in minimal solid waste residues when treated.

Particulates are the significant air pollutant emission from plastic and synthetic resin manufacture and from nitrate and phosphate fertilizer manufacturing. The nitrogen oxides and ammonia resulting from nitrate fertilizer production and the ammonia and fluorides from nitrogenous fertilizers are largely recovered and do not substantially contribute to solid waste residues. Carbon black manufacturing methods emit particulates,

TABLE X-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Phosphoric acid	Wet process (fertilizer grade)	kkg P_2O_5	Flouride	20	169
			Particulates	-	169
	Thermal process	kkg P_2O_5	Particulates	67	10
			Fluorides	-	169
Sulfuric acid	Plant	kkg H_2SO_4	Particulates	1.5	89
			SO_2	20	169
Plastics	General	kkg product	Particulates	(2.5-5.0) 3.75	169
Phosphate fertilizers		kkg	Particulates	503[b]	89
Nitrogenous fertilizers		kkg	Particulates	80.6[c]	89
Carbon black	Channel process	kkg	Particulates	1,150	169
			Hydrocarbons	5,750	
	Thermal process		negl.	negl.	
	Gas furnace process		Particulates	1,100	
			Hydrocarbons	900	
	Oil furnace process		Particulates	1,100	
			Hydrogen sulfide	13	
			Hydrocarbons	200	

[a] For 1971 or most recent available information.

[b] Derived by converting the controlled emissions (236 X 10^6 kg) in Economics of Clean Air for 1967 to untreated by dividing by (100 - % control) /100,and dividing the dividend by the metric tons of P_2O_5 produced in 1967 (4.26 X 10^3 kkg).

[c] Reference 169 cites an emission level per ton of product; for nitrate fertilizers that is approximately one-sixth (1:6.24) the level for phosphate fertilizers. This ratio is used here in the absence of other data.

carbon monoxide, hydrogen sulfide, and hydrocarbons of these gases; only particulates and hydrogen sulfide are currently controlled in the United States.[169]

Water Pollutants. The industrial inorganic chemicals segment of SIC 28 accounts for significant water-borne effluents, of which a considerable portion is usually recovered as a part of the treatment process. These effluents contain primarily suspended solids (such as ash), cinders, metallic oxides, bricks and anodes, dissolved solids in the form of metallic sulfates, chlorides, "bitterns", and miscellaneous alkaline salts. Most of the waste stream containing suspended solids stems from brine purification and treatment processes, while dissolved solids are derived from a variety of distillation, cleaning, drying, recovery, and water treatment processes. Table X-2 lists untreated discharge factors, mostly for dissolved and suspended solids, for relevant processes in chemicals manufacture.

The waste streams produced in the manufacture of plastics and synthetics contain suspended solids and biological and chemical sludges. Biological sludge results primarily from end-of-pipe treatment of wastewater, while chemical sludge stems from processes such as neutralization and precipitation of inorganic chemicals. Suspended solids accumulate in the aeration and polishing lagoons into which the sludges are deposited. Table X-2 provides an estimate of the sludge-dry solids from the plastics and synthetic industry which must be disposed of to landfills after lagooning.

In the organic chemicals segment of SIC 28, data concerning water pollutants such as dissolved and suspended solids which are associated with the waste stream from production and waste treatment activities are generally unavailable from existing literature sources. Thus, the effluent wastes for organic chemicals manufacture are characterized in terms of BOD_5, as listed in Table X-2.

The confidence level of the discharge factors estimated in Tables X-1 and X-2 is 3, indicating a ±25 percent possible variation in the data.

Industry Description and Schematic.

Figures X-1 to X-8 illustrate the basic manufacturing steps in selected relevant chemicals of the industrial inorganics segment of SIC 28. Owing to the diversity of products, production methods, and treatment processes involved in this sub-sector, it becomes difficult to portray it on a single comprehensive schematic. Those chemicals that are major contributors to solid waste residues after air and water pollution treatment have been selected for individual representation.

TABLE X-2
SOURCES BEFORE TREATMENT OF WATER . POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Sodium chloride		kkg	DS[d]	150	251
			SS	0	
Sodium carbonate	Solvay process		DS	1,320	
			SS	90	
Titanium dioxide	Sulfate		DS	5,000	
			SS	0	
	Chloride (non rutile)		DS	184	
			SS	216	
	Rutile		DS	35	
			SS	40	
Chlorine-sodium hydroxide			DS	137	
			SS	13	
Sodium dichromate			DS	11	
			SS	47	
Sodium silicate			DS	5.0	
			SS	2.5	
Sodium			DS	145.5	
			SS	4.5	
Aluminum sulfate			DS	0	
			SS	3.5	
Sulfuric acid			DS	0.5	
			SS	0	
Nitric acid			DS	0.2	
			SS	0.05	
Hydrogen peroxide			DS	20	
			SS	0	
Hydrofluoric acid			DS	0	
			SS	4	
Miscellaneous chemicals			DS	1.25	
			SS	0.60	
Organic chemicals		kkg	BOD_5	61.3[b]	66,295
Plastics		kkg	Sludge dry solids	9.9[c]	253

TABLE X-2 (Cont.)

[a] For 1971 or most recent available information.

[b] Organic chemicals manufacture generations of BOD_5 is estimated as follows:

$$\frac{365.3 \text{ kg } BOD_5}{10^6 \text{ l wastewater}} \times 8173 \times 10^9 \text{ l wastewater/year} = 2986 \times 10^6 \text{ kg } BOD_5\text{/year}$$

(1968)[66,295] (2986 X 10^6 kg BOD_5 year)/48.7 X 10^6 kg organic chemical produced in 1968 (Ref. 295) = 61.3 kg BOD_5/kkg organic chemicals.

[c] Estimated average for the plastics industry for the subsectors presented in Ref. 253.

[d] DS = dissolved solids.

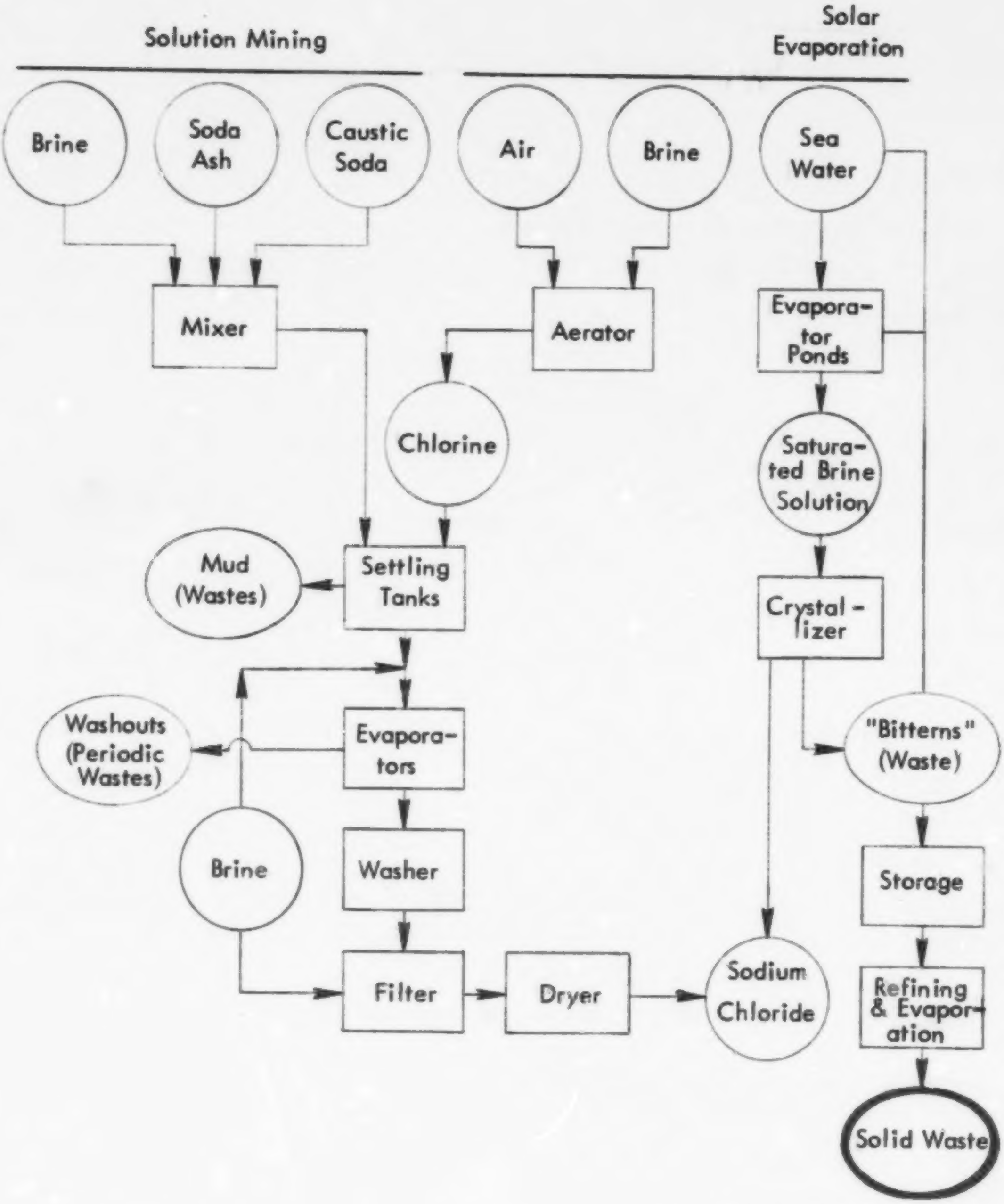
Solution Mining
Solar Evaporation
Brine
Soda Ash
Caustic Soda
Air
Brine
Sea Water
Mixer
Aerator
Evaporator Ponds
Chlorine
Saturated Brine Solution
Mud (Wastes)
Settling Tanks
Crystal-lizer
Washouts (Periodic Wastes)
Evaporators
"Bitterns" (Waste)
Brine
Washer
Storage
Filter
Dryer
Sodium Chloride
Refining & Evaporation
Solid Waste

FIGURE X-1
INDUSTRY SCHEMATIC:
SODIUM CHLORIDE VIA
SOLAR EVAPORATION AND
SOLUTION MINING PROCESSES

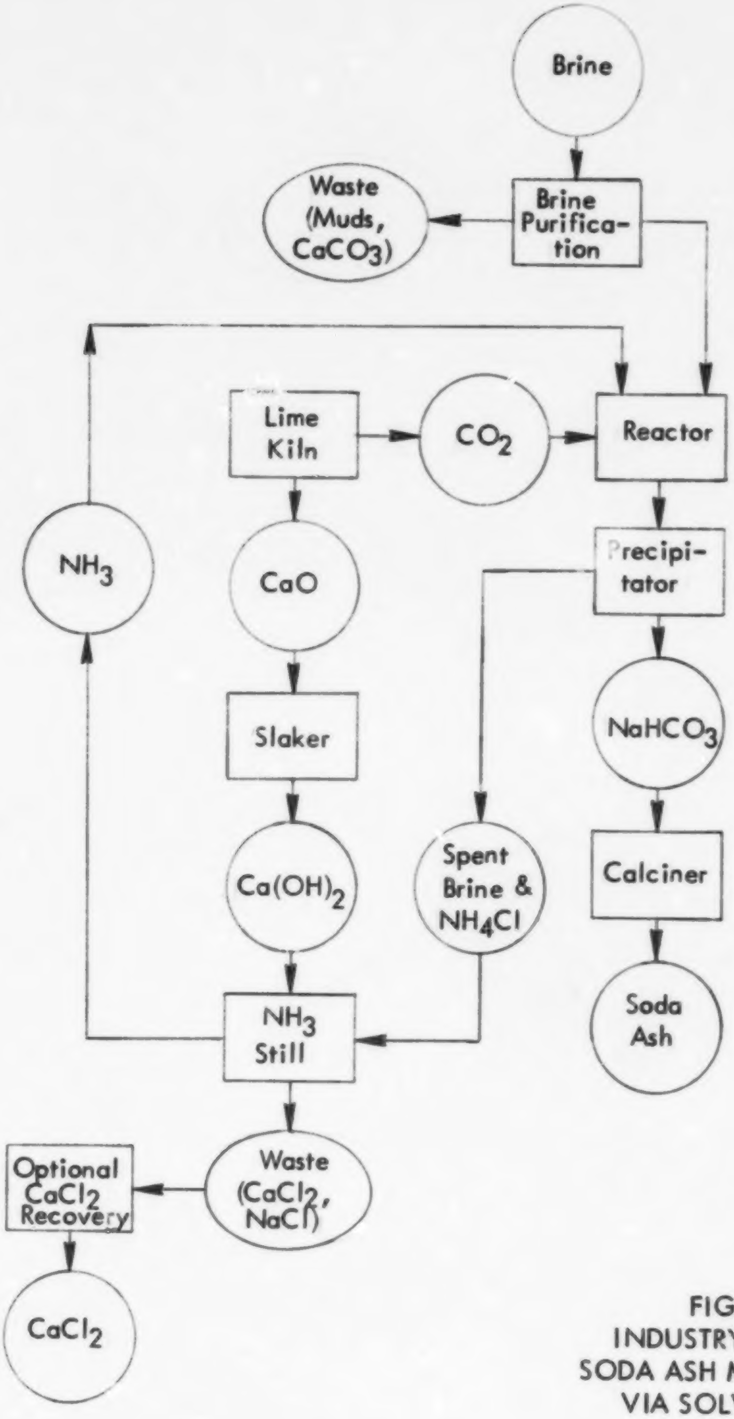
Brine
Waste (Muds, CaCO3)
Brine Purification
Lime Kiln
CO2
Reactor
NH3
CaO
Precipitator
Slaker
NaHCO3
Ca(OH)2
Spent Brine & NH4Cl
Calciner
Soda Ash
NH3 Still
Optional CaCl2 Recovery
Waste (CaCl2, NaCl)
CaCl2

FIGURE X-2
INDUSTRY SCHEMATIC:
SODA ASH MANUFACTURE
VIA SOLVAY PROCESS

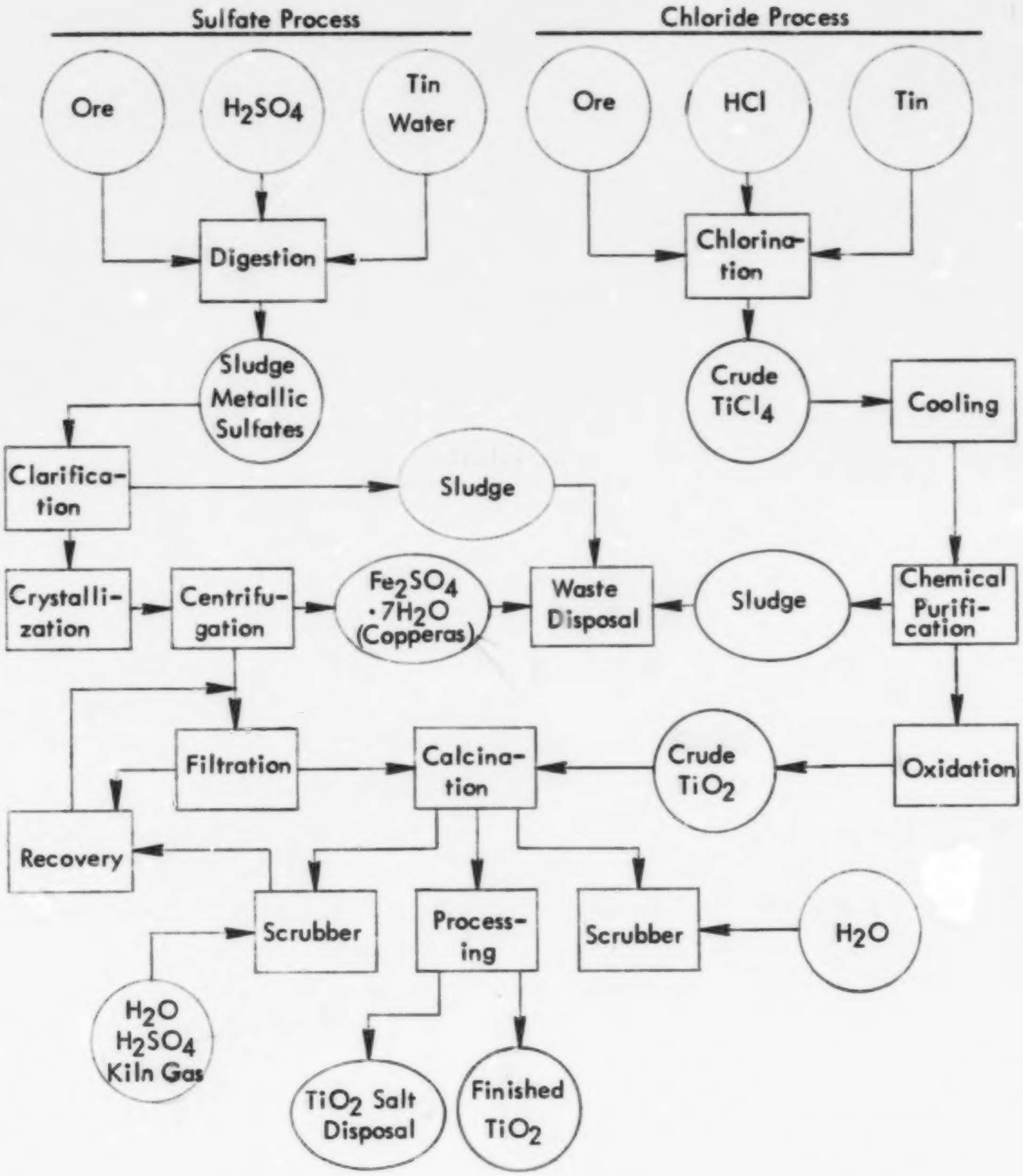
Sulfate Process
Chloride Process
Ore
H2SO4
Tin Water
Ore
HCl
Tin
Digestion
Chlorination
Sludge Metallic Sulfates
Crude TiCl4
Cooling
Clarification
Sludge
Crystallization
Centrifugation
Fe2SO4 · 7H2O (Copperas)
Waste Disposal
Sludge
Chemical Purification
Filtration
Calcination
Crude TiO2
Oxidation
Recovery
Scrubber
Processing
Scrubber
H2O
H2O H2SO4 Kiln Gas
TiO2 Salt Disposal
Finished TiO2

FIGURE X-3
INDUSTRY SCHEMATIC:
TiO_2 PRODUCTION BY
SULFATE AND CHLORIDE PROCESSES

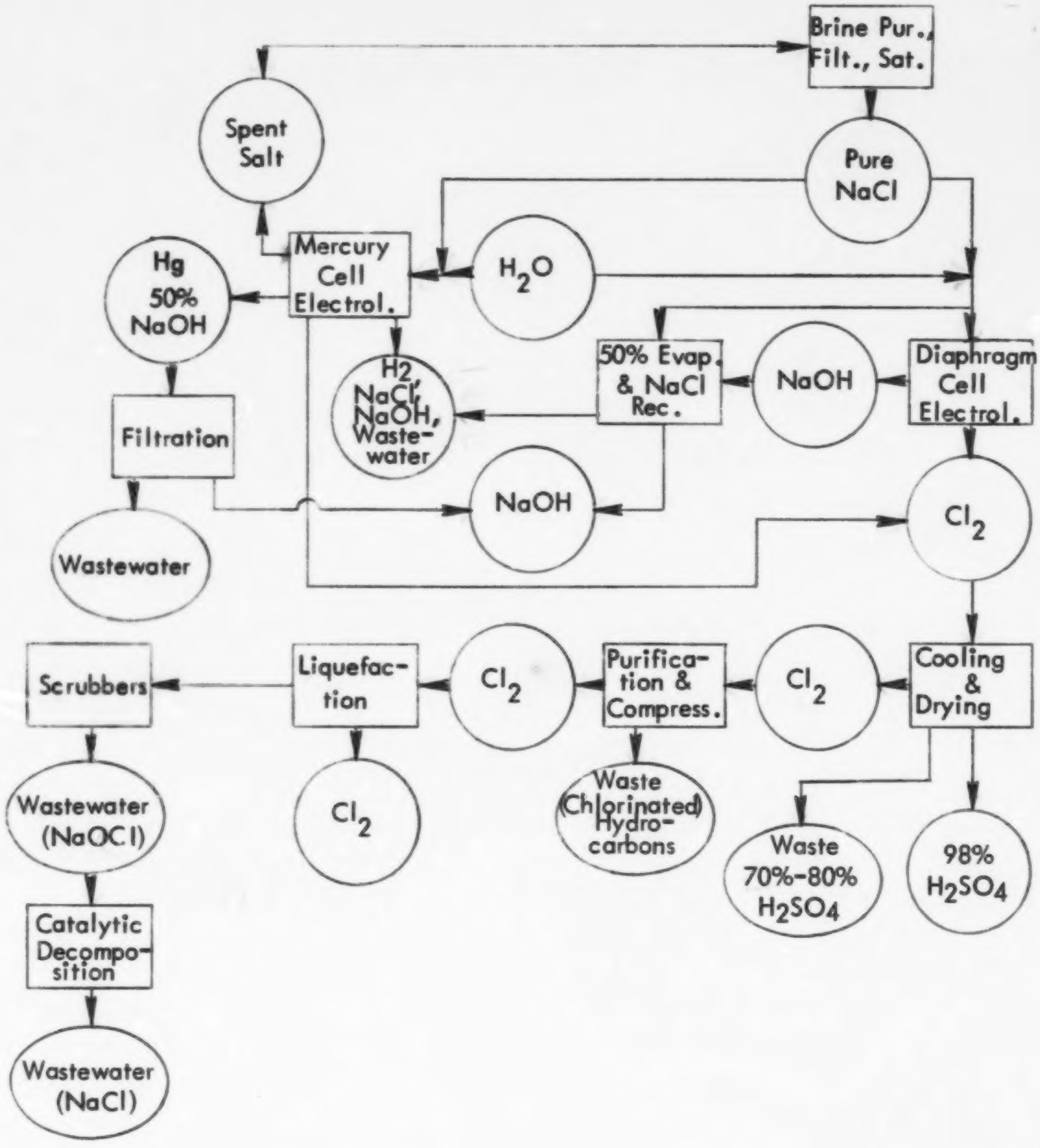
Brine Pur., Filt., Sat.
Spent Salt
Pure NaCl
Hg 50% NaOH
Mercury Cell Electrol.
H_2O
50% Evap. & NaCl Rec.
NaOH
Diaphragm Cell Electrol.
H2, NaCl, NaOH, Wastewater
Filtration
NaOH
Cl_2
Wastewater
Scrubbers
Liquefaction
Cl_2
Purification & Compress.
Cl_2
Cooling & Drying
Wastewater (NaOCl)
Cl_2
Waste (Chlorinated) Hydrocarbons
Waste 70%-80% H_2SO_4
98% H_2SO_4
Catalytic Decomposition
Wastewater (NaCl)

FIGURE X-4

INDUSTRY SCHEMATIC:
CHLOR ALKALI PROCESS
VIA DIAPHRAGM CELL AND
MERCURY CELL ELECTROLYSIS

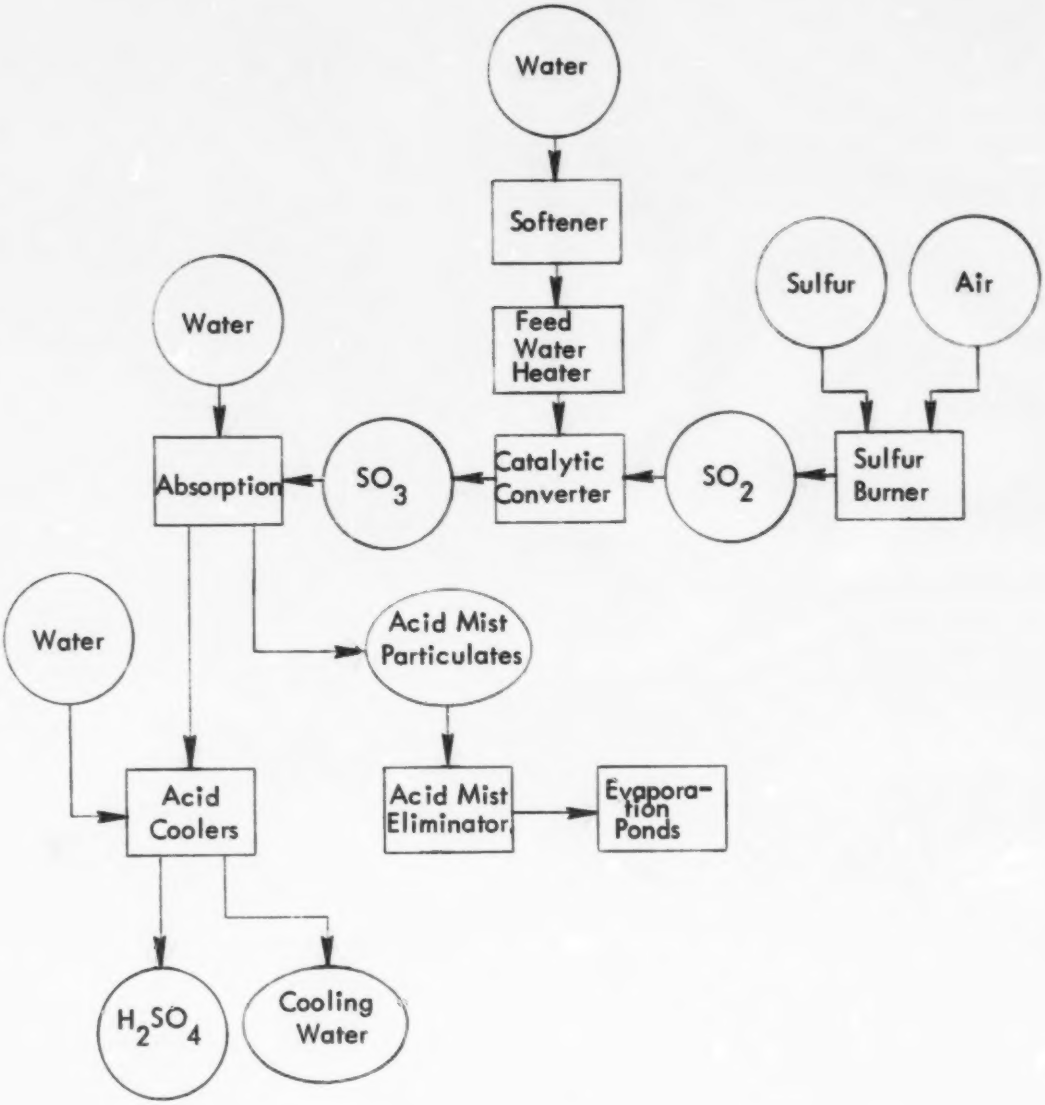
Water
Softener
Feed Water Heater
Sulfur
Air
Water
Absorption
SO_3
Catalytic Converter
SO_2
Sulfur Burner
Water
Acid Mist Particulates
Acid Coolers
Acid Mist Eliminator
Evaporation Ponds
H_2SO_4
Cooling Water

FIGURE X-5

INDUSTRY SCHEMATIC:
SULFURIC ACID MANUFACTURE
VIA CONTACT PROCESS

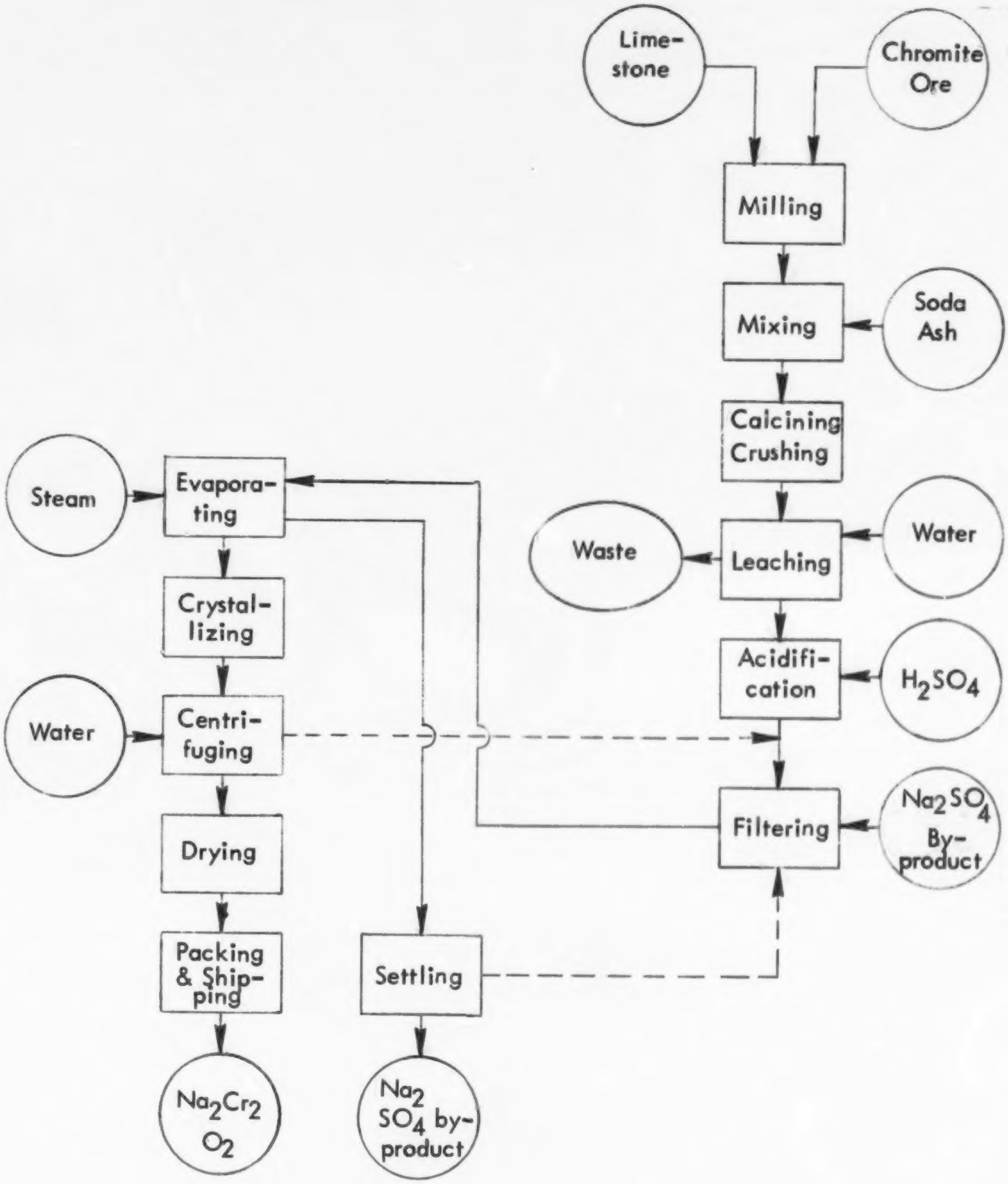
Lime-stone
Chromite Ore
Milling
Mixing
Soda Ash
Calcining Crushing
Steam
Evaporating
Waste
Leaching
Water
Crystallizing
Acidification
H_2SO_4
Water
Centrifuging
Filtering
Na_2SO_4 By-product
Drying
Packing & Shipping
Settling
$Na_2Cr_2O_2$
Na_2SO_4 by-product

FIGURE X-6
INDUSTRY SCHEMATIC:
SODIUM DICHROMATE
AND SODIUM SULFATE
PRODUCTION

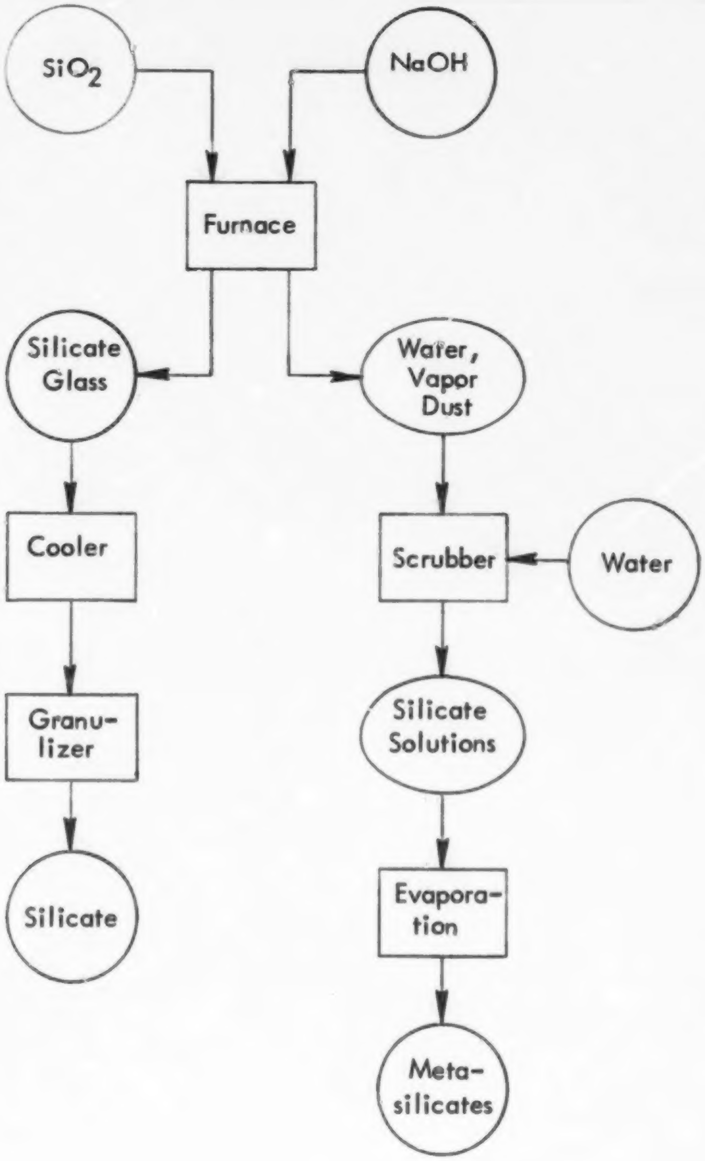
SiO2
NaOH
Furnace
Silicate Glass
Water, Vapor Dust
Cooler
Scrubber
Water
Granulizer
Silicate Solutions
Silicate
Evaporation
Metasilicates

FIGURE X-7
INDUSTRY SCHEMATIC:
SODIUM SILICATE
MANUFACTURE

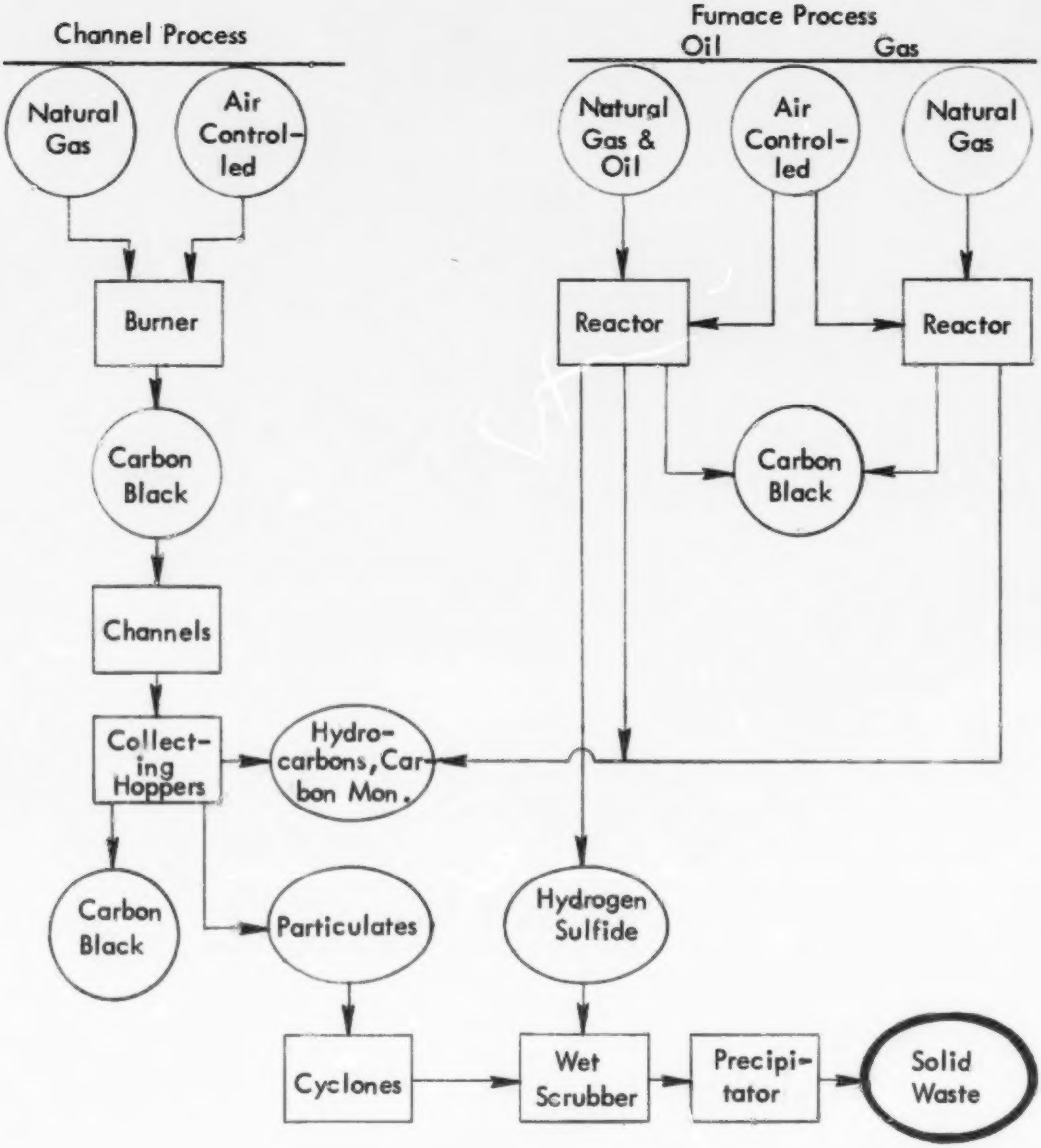
Channel Process
Furnace Process
Oil
Gas
Natural Gas
Air Controlled
Natural Gas & Oil
Air Controlled
Natural Gas
Burner
Reactor
Reactor
Carbon Black
Carbon Black
Channels
Collecting Hoppers
Hydrocarbons, Carbon Mon.
Carbon Black
Particulates
Hydrogen Sulfide
Cyclones
Wet Scrubber
Precipitator
Solid Waste

FIGURE X-8
INDUSTRY SCHEMATIC:
CARBON BLACK
MANUFACTURE

Economic Forecasts.

Table X-3 presents available forecasts for the chemicals selected for study in this report. These forecasts of production and demand, and occasionally capacity levels, were gathered mostly from secondary sources which project economic data for the years 1971, 1975, 1980, and 1985. Table X-4 is derived from the data in Table X-3. Assumptions in these projections are explained in footnotes to Table X-4.

Industrial inorganic chemicals have shown a steady overall upward trend in the last ten years, and this growth pattern is expected to continue. With the exception of sulfate process titanium dioxide, sodium dichromate, sodium metal, and potassium metal, which are expected to remain constant at, or decline from, current output levels, all remaining inorganic chemicals are forecast to increase in output. The most significant increases have been projected for chlorine-sodium hydroxide, sulfuric acid, nitric acid, hydrochloric acid, and phosphoric acid, with annual growth rates in excess of 6 percent. High rates of increase have also been forecast for organic chemicals, plastics, and fertilizers. Although total production of carbon black is projected to show a modest but steady growth trend, the highly polluting channel process is expected to show a relative decline over the period under study and to be completely abandoned by 1985. The thermal process is forecast to increase and by 1985 to account for the major share of carbon black production; furnace processes are expected to register modest gains in output. The suggested overall confidence level of all forecasts presented in Table X-4 is 3, indicating a ±25 percent possible variation in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Wastes.

Air Pollutants. Discharge inventories for air pollutants capable of producing solid waste residues from treatment are listed in Table X-5. These levels of pollutant discharges were established assuming current technologies before treatment. By weight, sulfur oxides from sulfuric acid manufacture are the largest uncontrolled discharges. Particulates from fertilizer and carbon black production also are significant contributors to air pollution from chemicals manufacturing.

Water Pollutants. Table X-5 also contains estimates of total suspended solids, dissolved solids, sludge-dry solids, and BOD$_5$ generated from the manufacture of various relevant chemicals. Again, the estimates of water pollutant discharges were established under the assumption of current production technologies. Significant contributors to water pollution from chemicals manufacture include soda ash production (SS and TDS), NaCl and TiO$_2$ production (TDS), and organic chemicals production (BOD$_5$).

Owing to the likelihood of compounding the deficiencies in the economic forecast (Table X-4) and the air and water pollution discharge factors (Tables X-1 and X-2, respectively), the confidence level for the discharge inventory of pollutants is 2, indicating a ±50 percent possible variation in the data.

TABLE X-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 28

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Soda ash	Production	10^6 kkg	1972	6.71					308	1973
			1973	6.82					309	1973
			1972	6.80					127	1973
	Production								368	1972
	–synthetic		1972	3.97	3.88					
	–natural				2.60					
Sodium hydroxide	Production	10^6 kkg	1972	9.35	8.80				368	1972
			1973	9.80					368	1972
					8.80	12.34	16.06	20.51	127	1973
Sodium bicarbonate	Consumption	growth/yr.	Post. 1971	+2%					374	1972
	Production	10^3 kkg	1970	129.7	158.3				251	1973
Potassium hydroxide	Total demand	10^3 kkg	1972	158.8					205	1973
			1973	163.3					205	1973
			1977	186.0					205	1973
	Production	10^3 kkg	1970	159.0	180.0				251	1973
			1972	161.0					251	1973
Titanium dioxide	All processes	10^3 kkg	1973	788.6		929.2			377	1973
	Chloride process		1973	372.0		558.1			377	1973
	Sulfate process		1973	416.5		371.1			377	1973
	Production		1972	626.1	615.2				368	1972
			1973	644.3					368	1972

TABLE X-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 28

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Titanium dioxide (Cont.)	Production (Cont.)	10^3 kkg	1970	594	615				251	1973
			1972	623					251	1973
			1973	644					251	1973
Sodium	Total demand	10^3 kkg	1972	133.4	138.9				307	1972
			1976	99.8					307	1972
	Production		1970	155	139				251	1973
Potassium sulfate		10^3 kkg	1970	296	408				251	1973
Sodium diochromate and chromate	Production	10^3 kkg	1972	124	124				251	1973
			1970	140						
Potassium metal	Imports	% of supply	1970	42%				47%	386	1972
			2000	619.0					386	1972
	Production	kkg	1973	91	59				251	1973
			1970	285					251	1973
Sodium silicate	Total demand	10^3 kkg	1972	601.7					385	1973
			1977	680.6					385	1973
	Production		1972	601	569				251	1973
Sodium sulfate	Capacity	10^3 kkg	1973	1,644					367	1973
	Production		1972	1,225					308	1973
			1973	1,194					308	1973

TABLE X-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 28

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Nitric acid	Production	index	1970	100			200		337	1971
		10^6 kkg	1973	6.73	6.12				251	1973
		10^6 kkg	1972	6.37					251	1973
Sodium sulfite	Total demand	10^3 kkg	1972	225	219				307	1972
			1976	254					307	1973
			1970	222	185				251	1973
Hydrochloric acid	Production	10^3 kkg	1972	2,014	1,905				368	1972
			1973	2,132					368	1972
Hydrogen peroxide	Total demand	10^3 kkg	1972	63.5	59.8				380	1972
			1976	72.6					380	1972
	Production		1970	55.3	58.8				251	1973
			1972	68.0					251	1973
Hydrofluoric acid	Total demand	10^3 kkg	1972	317.6					369	1973
			1973	340.3					369	1973
			1977	435.6					369	1973
	Production		1972	301	199				251	1973
			1970	204					251	1973
Phosphoric acid	Production	10^6 kkg	1973	6.0	5.6				368	1972
		10^6 kkg	1972	5.8					368	1972
		index	1970	100			165		337	1971

TABLE X-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 28

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Phosphoric acid (Cont.)	Furnace (dry process)	10^6 kkg			1.64				417	1973
	Wet process	10^6 kkg			4.02				417	1973
Aluminum sulfate	Production	10^3 kkg	1972	1,020	1,084				251	1973
			1970	1,080						
Aluminum chloride (Al Cl_3)	Production	10^3 kkg	1972	30.8	26.4				251	1973
			1970	28.5						
Calcium chloride	Total demand	10^3 kkg	1972	953	874				381	1972
			1976	1,132						
Organic chemicals	Production	10^3 kkg	1970	59.2	59.5				295	1973
			1969	57.4					295	1973
			1968	48.7					295	1973
			1967	43.2					295	1973
		index			119	170	217	272	68	1973
Plastics	Production	10^6 kkg			9.4	15.2	22.7	32.7	127	1973
Phosphate fertilizer	Production	10^6 tons	1977	7.1					3	1972

TABLE X-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 28

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Nitrogen fertilizer	Production	10^6 kkg	1972	13.2					308	1973
			1973	14.1						
Carbon black	Production	Index	1970	100			135		337	1971
	Total production	10^6 kg	1970	1,331	1,370				363	1972
	Furnace (all)		1970	1,279	1,349					
	Oil furnace				1,071					
	Gas furnace				123					
	Thermal				155					
	Channel process		1970	52	21					
Chlorine	Total demand	growth/yr.	Post-1972	6%					382	1973
	Production	10^6 kkg	1972	9.9	9.4				368	1972
Chlorine gas	Production	10^6 kkg	1973	10.5						
			1973	10.4					373	1973
	Consumption	10^6 kkg	1990	34.0			19.1		383	1973
			1972	8.95	8.48				251	1973

TABLE X-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Chlorine gas and sodium hydroxide	Total production	10^6 kkg	8.64	127[a]	11.70	127[a]	16.15	127[a]	22.18	127[a]
	Diaphragm		6.48	251	8.77	251	12.11	251	16.63	251
	Mercury		1.73	251	2.36	251	3.23	251	4.44	251
	Other		0.43	251	0.53	251	0.81	251	1.11	251
Soda ash	Total production	10^6 kkg	6.44	127	7.17	127	7.98	127	9.07	127
	Solvay (synthetic)		3.88	368	4.32	b	4.81	b	5.47	b
	Natural		2.56	c	2.85	c	3.17	c	3.60	c
Sodium bicarbonate	Production	10^3 kkg	158.3	d	173.0	d	200.5	d	234.4	d
Caustic potash	Production	10^6 kkg	1.80	e	1.77	e	2.08	e	2.29	e
Titanium dioxide	Total production	10^3 kkg	615	368	683	f	792	f	918	f
	Chloride process		290	f	410	f	515	f	643	f
	-non-rutile		218	f	307	f	386	f	482	f

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Titanium dioxide (Cont.)	-rutile	10^3 kkg	72	f	103	f	129	f	161	f
	Sulfate process		324.8	f	273	f	277	f	275	f
Sodium chloride	Total production	10^6 kkg	43.2	410	46.7	g	51.6	g	57.0	g
	Solar evaporation		2.35	251	2.52	g	2.77	g	3.08	g
	Solution mining		5.93	251	6.40	g	7.07	g	7.81	g
Sodium		10^3 kkg	139	251	107	h	76	h	54	h
Sodium dichromate		10^3 kkg	125	251	135	i	135	i	135	i
Sodium silicate	Production	10^3 kkg	570	251	629	385	712	385	806	385
Nitric acid	Production	10^6 kkg	6.12	251	8.02	j	12.03	j	15.78	j
Sodium sulfite	Production	10^3 kkg	219	k	239	k	277	k	321	k
Sulfuric acid	Production	10^6 kkg	26.7	127	33.6	127	43.6	127	55.3	127
Hydrochloric acid	Production	10^3 kkg	1,905	368	2,304	l	2,940	l	3,751	l

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Hydrogen peroxide	Production	10^3 kkg	58.9	380	71.6	m	91.4	m	116.6	m
Hydrofluoric acid	Production	10^3 kkg	199	251	400.2	n	587.8	n	836.5	n
Potassium metal	Production	kkg	59	251	100	o	100	o	100	o
Phosphoric acid	Total production	10^6 kkg	5.66	417	6.70	p	9.06	p	11.70	p
	Furnace process		1.64	417	1.94	q	2.62	q	3.39	q
	Wet process		4.02	417	4.76	q	6.44	q	8.31	q
Miscellaneous industrial inorganic chemicals	Total	10^6 kkg	10.8	r	12.9	r	16.2	r	20.4	r
	Aluminum sulfate		1.084		1.128		1.186		1.246	
	Aluminum chloride		0.0264		0.0358		0.0435		0.053	
	Calcium chloride		0.874		1.087		1.354		1.687	
Phosphate fertilizer	Production (P_2O_5)	10^6 kkg	6.28	s	6.94	s	7.85	s	8.88	s
Nitrogen fertilizer	Production	10^6 kkg	12.94	t	16.88	t	22.77	t	30.24	t

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Total fertilizer	Production	10^6 kkg	19.88	u	24.64	u	31.44	u	39.92	u
Carbon black	All production	10^6 kkg	1.48	363	1.68	v	1.99	337	2.37	v
	Channel process[b]		0.02	363	0.02	w	0.02	w	0.02	w
	Thermal furnace[c]		0.17	363	0.24	x	0.39	x	0.61	x
	Oil furnace[d]		1.17	363	1.25	y	1.35	y	1.47	y
	Gas furnace[e]		0.13	363	0.16	z	0.21	z	0.27	z
Organic chemicals		10^3 kkg	59.5	295	85	aa	108	aa	136	aa
Plastics	Total production	10^6 kkg	9.4	127	15.2	127	22.7	127	32.7	127

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

[a] Chlorine and sodium hydroxide are jointly manufactured via the diaphragm and mercury electrolysis cells. Since they produce pollutants that are treated by the same processes, the two chemicals are pooled and the same level of output forecast for both chemicals.

The forecasts based on forecasts obtained from Ref. 127 are slightly modified to arrive at a single forecast for chlorine and sodium hydroxide. Production of sodium hydroxide is slightly underestimated, while the production of chlorine is slightly overestimated.

[b] Production of synthetic soda ash (solvay) is forecast to maintain a 60 percent share of total soda ash output in 1975, 1980, and 1985. Sixty percent of total output represents the average share of solvay in the period 1969-72 and was adopted here as a continuing trend in the absence of any other known trends.

[c] Output of natural soda ash is projected to remain a constant 40 percent share of total soda ash output. The rationale for these projections for 1975, 1980 and 1985 is the same as in (a) above.

[d] The production of sodium bicarbonate is projected to grow at a 3 percent annual compound rate through 1985. This rate of increase represents an average of the forecasted growth trends advanced in Refs. 374 and 376.

[e] Output of potassium hydroxide (caustic potash) is projected to increase at a compound annual rate of 3.25 percent through 1985. This growth trend corresponds to the average of the growth forecasts in Refs. 205 and 416.

[f] Total output of titanium dioxide is projected to increase at an annual compound rate of 3 percent through 1985. This trend was established by extrapolating the average growth for the period 1970 to 1973.

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

[f] (Cont.)

Production capacity for the chloride process is expected to increase from 47 percent to 60 percent of total capacity by 1975, while the sulfate process will decline in capacity from 53 percent to 40 percent. It is projected that the chloride process will increase its share of capacity to 70 percent by 1985.

Given the total production forecasts submitted above, the outputs derived from the two processes are obtained by dividing the total output according to the share of total capacity for 1975 and 1985. 1980 projections were obtained by interpolation of the trends established above.

[g] 1971 total production of sodium chloride was obtained from Ref. 410, and output via solar evaporation and solution mining was obtained from Ref. 251. Forecasts for 1975, 1980 and 1985 were independently estimated in the absence of any published forecasts. Using past data,an annual growth rate of 2 percent for total production, as well as for both the solar evaporation and solution mining methods,was used.

[h] Based on a 1976 forecast of demand of 99.8×10^6 kkg presented in Ref. 307, a declining trend of 7 percent per year was established and used to extrapolate the output of sodium metal through 1985.

[i] In the absence of any other data except output levels for 1970-72, it is projected that production of sodium dichromate will regain the 1970 peak of 140×10^3 kkg by 1975 and thereafter remain constant.

[j] 1971 data obtained from Ref. 251. Forecast for 1980 presented in Ref. 337 was used to derive a rate of growth. Thus, the annual growth rate of 7.0 percent was used to make projections for 1975 and 1985 by interpolation and extrapolation, respectively.

[k] Under the assumption that total demand is met by domestic production, demand growth forecasts were used for making production forecasts through 1985.

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

[l] Production forecasts for 1975 through 1985 were based on extrapolation of 1970-73 trends, using the derived growth rate of 5.00 percent.

[m] The output of hydrogen peroxide was assumed to correspond to the growth rate in domestic demand. Thus, the projected growth rate of demand for 1972-77, contained in Ref. 307, was used to forecast the output of hydrogen peroxide.

[n] Under the assumption that production of hydrofluoric acid matches total demand, production forecasts were established using the available forecasts of demand growth for 1972-1977 contained in Ref. 369. The 5.00 percent annual growth rate in demand was used to extrapolate for 1980 and 1985 to obtain production forecasts.

[o] The 1971 output level of potassium metal was obtained from Ref. 251. Based on a 1973 production estimate of 91 kkg, which indicates reversal of a declining trend since 1970, it was projected that production will rise to 100 kkg in 1975 and remain constant thereafter.

[p] The 1971 estimate for production of phosphoric acid was obtained from Ref. 417. The 1980 forecast of total output contained in Ref. 337 provided the basis for establishing a 1970-80 growth rate of 5.25 percent per year. Both 1975 and 1985 outputs were derived using the above growth pattern.

[q] Ref. 417 provided the current distribution of phosphoric acid output between the furnace (dry) process and the wet process. In the absence of other information on trends, it was assumed that this current distribution will be maintained through 1985.

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

[r] Miscellaneous industrial inorganic chemicals is a group which aggregates those chemicals regarded as relatively insignificant either in the volume of production and/or volume of pollutant discharges. 1971 level of production for this group was obtained by taking the residual after deducting the sum of the output levels for all the inorganic chemicals which are individually forecast above from total output of industrial inorganic chemicals. The miscellaneous inorganic chemicals were forecast using a growth rate of 4.7 percent per year, a trend that approximates the overall growth trend for the inorganic chemicals industry.

[s] Forecasts have been estimated on the basis of projections provided by Ref. 3, which presents a 1977 forecast of phosphate fertilizer production. Data for 1971 through 1985 were obtained using a calculated 2.25 percent annual growth rate.

[t] Owing to the absence of data on production of nitrogen fertilizer, consumption projections were used to forecast the output of nitrogenous fertilizers. Based on 1972 and 1973 production figures, it was established that domestic consumption accounts, on the average, for 57 percent of total output. Thus, production was projected to be 1.75 times the level of domestic consumption.

[u] Total production for the fertilizer industry is composed of the sum of production - current and projected - of the nitrogen and phosphate fertilizer industries.

[v] The forecast of total carbon black production in 1980 was obtained from Ref. 337. 1975 and 1985 forecasts were established by trend interpolation and extrapolation, respectively, using 3.5 percent annual growth rate.

[w] Based on communication with industry sources as shown in Refs. 365 and 366, it is expected that production via channel process will stay at the same, or at a slightly reduced level, through 1985.

TABLE X-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 28

[x] Thermal furnace production was forecast, according to Refs. 365 and 366, to register rapid growth. The projected annual growth rate is 10 percent.

[y] Oil furnace production will show a very modest increase in volume and a relative decline in its share of output. The expected annual rate of growth is 1.6%.

[z] Gas furnace production was forecast to grow at a moderately high rate of 5.25% per annum, increasing its share of total carbon black production.

[aa] Derived by multiplying the increase in the index from Ref. 68 by the output for the 1971 base year from Ref. 295.

TABLE X-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
AIR POLLUTANTS						
Particulates:						
Sulfuric acid	General	89	40	50	65	83
Carbon black	Channel process	169	23	23	23	23
	Gas process	169	143	176	231	291
	Oil process	169	1,287	1,375	1,485	1,617
	Thermal	169	neg.	neg.		
All plastics		169	38.25	61.57	91.91	132.37
Nitrate fertilizers	Total production	a	1,043	1,361	1,836	2,438
Phosphate fertilizers	Total production	a	3,161	3,489	3,948	4,467
Phosphoric acid	Thermal process	169	110	130	176	227
Total particulates			5,845	6,666	7,856	9,278
Fluorides:						
Phosphoric acid	Wet process	169	81	96	129	167
Sulfur oxides:						
Sulfuric acid	Total production	169	534	672	872	1,106

TABLE X-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Hydrogen sulfide:						
Carbon black	Channel	169	n.d.			
	Gas furnace		n.d.			
	Oil		15	16	17	19
	Thermal		n.d.			
WATER POLLUTANTS						
Suspended solids:						
NaCl	Solution mining	251	6.5	7.0	7.7	8.6
Sodium dichromate	Total production		5.9	6.3	6.3	6.3
Soda ash	Solvay process		349.2	388.8	432.9	492.3
TiO_2	Chloride		50.0	70.5	88.6	110.6
Sodium silicate	Total production		1.4	1.6	1.8	2.0
NaOH-Cl	Diaphragm process		84.2	114.1	157.5	216.3
Hydrofluoric acid	Total production		0.8	1.6	2.3	3.2
Sodium (metal)	Total production		0.6	0.5	0.3	0.2
Misc. chemicals	Total production		6.5	7.7	9.7	12.2
Total suspended solids			505.1	598.1	707.12	851.7

TABLE X-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged 1971	1975	1980	1985
Dissolved solids:		251				
NaCl			6,473.5	6,998.0	7,732.3	8,541.4
Soda ash	Solvay process		5,121.6	5,702.4	6,349.2	7,220.4
TiO_2	Sulfate process		1,624.0	1,365.0	1,385.0	1,375.0
NaOH-Cl	Mercury cell		237.0	1,201.5	442.5	608.3
	Diaphragm cell		887.8	323.3	1,659.1	2,213.9
Sodium (metal)	Total production		20.2	15.6	11.1	7.9
Sulfuric acid	Total production		13.3	16.8	21.8	27.6
Sodium dichromate	Total production		1.3	1.5	1.5	1.5
Hydrofluoric acid	Total production		neg.	neg.	neg.	0.1
Sodium silicate	Total production		2.9	3.1	3.5	4.0
TiO_2	Chloride process		42.6	60.0	75.5	94.2
Misc. chemicals	Total production		13.5	16.1	20.3	25.5
Total dissolved solids			14,437.7	15,703.3	12,701.8	20,117.8
Sludge-dry solids:						
Plastics	General	251	93.1	150.5	224.7	323.7

TABLE X-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 28

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
BOD_5:						
Organic chemicals		66,295	3,647	5,210	6,620	8,336

Neg = negligible contribution to pollutant load.

Likely Pollution Treatment Processes.

Air Pollutants. Table X-6 presents alternative treatment processes available for pollutant discharges for selected relevant segments of the chemical industry. Air pollution treatment systems for production of these chemicals generally involve some combination of scrubber devices, cyclones, spray towers, and fabric filters exhibiting high levels of treatment efficiency, i.e., ranging from 90 to 99.9 percent. Since a large number of these treatment systems involve the use of wet scrubbers and spray towers, these treatments will discharge suspended and dissolved solids to water, which in turn is subjected to water pollution treatments.

Water Pollutants. The water pollution discharges derived from the industrial inorganic chemicals segment are subjected to a variety of treatment methods, as detailed in Table X-6. Suspended solids are largely treated by passing the wastewater through settling ponds where settleable solids are removed with a high degree of efficiency. This and other physical or mechanical removal methods create dry residues approximately equal in weight to the suspended solids removed. The other pollutants from this segment, which consist primarily of metallic sulfates, chlorides, and other salts (classified as dissolved solids), may be treated by one or more of the following processes: neutralization, catalytic conversion, evaporation and recovery, or landfill disposal; treatment efficiencies will vary, depending on specific treatment combinations. Water pollutants from organic chemicals manufacturing may be subjected to both in-process controls and end-of-pipe treatment processes.

Some of the water pollution control methods (such as adsorption, solvent extraction, and distillation) are widely used for physical separation of wastewater from aqueous solutions containing recoverable by-products.[294] End-of-pipe treatment technologies involve the use of biological systems including the activated sludge process, extended aeration, aerated lagoons, trickling filters, and anaerobic and faculative lagoons.[294] These systems show an average level of treatment efficiency of about 95 percent, while BATEA treatment systems (from the suggested industry effluent guidelines) are expected to show efficiency levels of 99 percent.[294]

The confidence level for the data in this section is 3, indicating a ±25 percent possible variance in the data.

Reuse Potentials for Solid Waste Residues Produced by Pollution Treatment Processes.

The extent to which solid waste residues can be reused in the diverse chemicals manufacture industry is a function of both the source of the waste and the nature of treatments employed. For instance, the "bitterns" solution from sodium chloride solar evaporation may be stored and continually reworked to obtain sodium chloride such that 100 percent of the solid residue from the solar process is reused.[251] Table X-7 lists estimated reuse percentages of solid wastes from pollution control in the chemicals industry. The larger portion of industrial inorganic chemicals yields solid residues in the form of metallic salts which cannot be recycled. Organic chemicals, fertilizer,

TABLE X-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
AIR POLLUTANTS							
Sulfuric acid	Plant	Particulates	Acid mist eliminators	93-97	1		169
		Sulfur oxides	Dry adsorption	90	1		
			Alkali scrubber	90	2.2		
Phosphoric acid	Thermal process	Particulates	Packed tower	97	1		10,169
			Venturi scrubber	96	1		
			Glass fiber mist eliminator	98	1		
			Wire mesh mist eliminator	98	1		
			High-pressure drop mist eliminator	100	1		
			Electrost. precip.	99	1		
	Wet process	Particulates	Spray towers and settling pond	90	1		65
		Fluorides	Venturi scrubber	90	1		65
Plastics	General	Particulates	Fabric filter and miscellaneous recovery systems	98-99	1		169

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
CAPABLE OF GENERATING SOLID WASTE
SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Phosphate fertilizer	Total production	Particulates	Wet scrubbers	98	1		11
			Fabric filter	99	1		
Nitrate fertilizer	Total production	Particulates	Wet cyclone	70	1		11
			Dry cyclone	90	1		
			Wet screen scrubber with cyclones	95–97	1		
Carbon black	Oil & gas furnace	Particulates	Cyclone	90	1	n.d.	169
			(Cyclone + scrubber)	97	1	n.d.	
	Oil furnace	Hydrogen sulfide	HOCl wet scrubber plus precipitation	95 95	4		91
WATER POLLUTANTS							
Chlorine and sodium hydroxide							
Diaphragm cell	Barometer-condenser	SS, NaCl	Settling pond	≈ 100	1	0.049/kkg	
			Evaporation and recycling	80	0	$0.32/kkgCl	
		NaOH	Neutralization	80	0		
	Non-contact cooling	NaCl, NaOH		≈ 100	None	0.34/kkgCl	

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Mercury cell		HOCl, NaCl, Na_2SO_4	Catalytic conversion plus evaporation	≈100	1	$1/kkg Cl or .55/kkg products	251
		Chlorinated HC	Extraction and incineration	≈100	0		251
			Extraction and land disposal	≈100	1		251
Na_2CO_3	Solvay	SS	Settling ponds	100	1	0.51	251
			Settling ponds plus clarification	≈100	1		
		TDS	Settling ponds plus partial steam (20%)				
			Evaporation to recover $CaCl_2$	12	1	1.22	
			Deep well disposal after $CaCl_2$ recovery	≈100	n.a.	0.55	
			Deep well disposal No Ca Cl_2 recovery	≈100	n.a.	1.76	
TiO_2	Chloride method	SS	Pond settling	≈100	1	2.35	a
		HCl and hydroxides	Neutralization plus ponds or clarifier-thickener	100	1	40	251

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
CAPABLE OF GENERATING SOLID WASTE
SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
		Soluble salts from neutralization	Demineralization and evaporation	≈ 100	1	29/kkg	251
	Sulfate process	H_2SO_4 and metal sulfates	Full neutralization plus pond settling or clarifier-thickener	≈ 100	1.2^c	$2.12/kkg	251,252
		Soluble $CaSO_4$ from neutralization	Demineralization plus evaporation	≈ 100	1	106/kkg	251,252
Sodium chloride	Solvay	TDS (bitterns)	Storage ponds	100	1	2.42/kkg NaCl	251
	Solution mining	NaCl, TDS	Isolation of spills	100	1		
			Partial recycle to brine cavity	88-100	1	0.28-0.45/ kkg NaCl	251
Sulfuric acid							
	Sulfur burning	Spills, leaks		≈ 100	1		251
	Regen plant	Spills, leaks	Settling ponds	≈ 100	1		
		Sodium sulfate					
		Weak sulfuric acid	Neutralization	≈ 100	1		

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Sodium metal			Settling ponds	≈100	1		
Hydrofluoric acid		Suspended solids	Settling ponds	90	1		251
			Landfill	90	1		251
		Dissolved solids	Neutralization	90	1		251
Sodium silicate		Suspended solids	Settling pond	99	1		251
		Suspended solids	Settling pond plus neutralization	99	1		251
			Settling pond plus neutralization, plus evaporation and recovery	≈100	1		251
Sodium bicarbonate		Suspended solids	Settling ponds	≈100	1	30	251
		Dissolved solids	Evaporation	≈100	1	4.40	251
Aluminum sulfate		Suspended solids	Settling ponds	≈100	1		251

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 28

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: \$ per Physical Unit	Ref. No.
Misc. industrial inorganic chemicals		Suspended solids	Settling ponds	n.d.			
		Dissolved solids	n.d.	n.d.			
Organic chemicals		BOD_5	BPCTA	95	0.1[a]		294
			BATEA	98.99	0.1[a]		294
			BPCTA, BATEA plus incineration	n.a.	0.05[b]		294
Plastics	General	Sludge-dry solids	BPCTA, BATEA	n.d.	n.d.		251

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[a] Based on data for sludge produced from best practicable control technology currently available (BPCTA) from Ref. 294 for a typical plant assuming a 260 day work year:

$$\frac{.05 \times 10^6 \text{ lb product}}{\text{day}} \times \frac{260 \text{ days}}{\text{year}} \times \frac{0.4536 \text{ kg}}{\text{lb}} \times \frac{79 \text{ kg } BOD_5}{10^3 \text{ kg product}} = \underline{466 \times 10^3\ BOD_5\text{/year per plant}}$$

$$\text{Sludge} = 300 \text{ cubic yards (ref. 294)} \times 27 \text{ ft}^3 \times \frac{20}{100} \text{ solids (ref. 294)} \times \frac{62.3 \text{ lbs density}}{\text{ft}^3} \times \frac{.4536 \text{ kg}}{\text{lb}} =$$

45.8×10^3 kg Sludge cake

TABLE X-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE
SIC 28

[a] (Cont.)

$$\frac{45.8 \times 10^3 \text{ kg sludge cake}}{466 \times 10^3 \text{ kg BOD}_5} = 0.1 \text{ kg sludge cake solids per kg BOD}_5.$$

The above data is for category "D" in Ref. 294. Other categories held similar ratios.

[b] Ref. 294 states that half of the sludge cake solids are thermally oxidized during incineration.

[c] Calculated based on the ratio of the weight of calcium sulfate to sulfuric acid (1.39), reduced slightly for soluble calcium sulfate and for the presence of metal sulfates which are precipitated out without chemical combination.

TABLE X-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 28

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Phosphate fertilizers	Production	Wet scrubbers	75	169,296	Suspended solids
-particulates		Fabric filters	50		
-suspended solids		Settling pond/ thickener	0	297	Calcium phosphates
		Lime precipitation	0	297	Calcium phosphate and fluoride
Nitrate fertilizers - particulates	Production	Wet cyclone	50	169,296	
		Dry cyclone	50		
		Wet screen scrubbers with cyclones	50		
Carbon black - particulates	Channel process	None	0	169	None
	Gas furnace process	Electrostatic precipitators & baghouse	0		Particulates with high hydrocarbon content
	Oil furnace process	Electrostatic precipitators & baghouse	0		Particulates with high hydrocarbon content
Phosphoric acid - particulates	Thermal process	Packed tower	0	169	Particulates, H_3,PO_4
		Venturi scrubber	0	169	Particulates, H_3,PO_4
		Wire mesh mist eliminator	0	169	Particulates, H_3,PO_4

TABLE X-7 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES
PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 28

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref No.	Description/Disposal of Residue
Phosphoric acid - particulates (Cont.)	Thermal process (Cont.)	High pressure drop mist eliminator	0	169	Particulates, H_3,PO_4
		Electrostatic precipitator	0	169	Particulates
- fluorides	Wet process	Venturi scrubber	0	65	HF, CaF_2, H_2SiO_3, $CaSiO_3$
Sulfuric acid - particulates	Plant	Acid mist	100	169	None
- sulfur oxides		Dry adsorption	100	169	Converted to SO_3 to produce H_2SO_4, $CaSO_4$, $CaSO_3$
		Alkali scrubber	0	169	
- dissolved solids	Production	Neutralization	100	251	
Plastics - particulates	General	Fabric filter & misc. recovery systems	75	169	Monomers, sublined solid products
			75	169	Monomers, sublined solid products
- sludge, dry solids		Primary treatment	0	251	sludges of $CaSO_4$, organics, $ZnSO_4$
NaOH - Cl - suspended solids	Mercury cell	Settling ponds	0	251	
		Evaporation	0		
		Return to brine cavity			
	Diaphragm cell	Settling ponds	0		

TABLE X-7 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 28

Item and Pollutant	Process or Activity	Treatment Process	% Reuse		Description/Disposal of Residue
TiO_2					
- suspended solids	Chloride method	Settling ponds	0	251	Iron, titanium and other metal oxides and hydroxides, and coke
	Sulfate process	Settling ponds	0		Metal sulfates, impurities
$NaCO_3$					
-suspended solids	Solvay process	Settling ponds	0	251	Calcium carbonate, ash
-dissolved solids		Clarification	0		Cinders, and silicon dioxide
	Solvay process	Evaporation to recover $CaCl_2$	62	251	$CaCO_3$, CaO, $CaSO_4$ and NaCl
		Deep well disposal, no $CaCl_2$ recovery	0	251	
		Deep well disposal after $CaCl_2$ recovery	0	251	
$Na_2Cr_2O_7$	Total Production				
- suspended solids		Settling ponds	0	251	$CaCO_3$, iron hydroxides
- dissolved solids		Evaporation	0	251	Fe, other metal sulfates
NaCl	Solution mining				
- suspended solids		Misc. controls	0	251	Ca, Mg, Fe carbonates
- dissolved solids		Storage ponds	100	251	"Bitterns" of sea salt reduced in NaCl content
Hydrofluoric acid	Total production				
- suspended solids		Settling ponds	100	251	
- dissolved solids	Production	Neutralization	0	251	$CaSO_4$

TABLE X-7 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 28

Item and Pollutant	Process or Activity	Treatment Process	% Reuse		Description/Disposal of Residue
Sodium silicate	Total production	Settling pond	100	251	Sodium silicate, silica and other silicates
		Settling pond plus neutralization			
Sodium metal	Total production	Settling ponds	0	251	
Sodium silicate - dissolved solids	Production	Evaporation pond	0	251	
Sodium (metal) - dissolved solids	Production	Settling ponds	0	251	NaCl, $CaCl_2$, Na_2SO_4

and carbon black manufacture similarly yield little solid residue that can be reused. The plastics and synthetic materials segment, however, shows a high capability for reuse of solid residues to the extent of about 75 percent.[169] Owing to the incomplete nature of available information on extent of reuse of waste residues in the chemicals industry, the confidence level for the data in Table X-7 is 2, indicating a 50 percent possible variation in the data.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables X-8 through X-11 forecast solid residues from pollution control in chemicals manufacture for 1971, 1975, 1980, and 1985, respectively. As shown in Table X-8, the manufacture of all relevant chemicals yields air pollutants (particulates, sulfur oxides,and fluorides) which,when treated, generated about 3,743 x 10^6 kg of solid wastes in 1971. Treatment of particulate emissions from nitrate and phosphate fertilizer and carbon black manufacturing plants contributed an estimated 2,655 X 10^6 kg of residues. An additional 1,060 x 10^6 kg was produced by control of sulfur oxides in sulfuric acid manufacture through dry adsorption and scrubbing treatment.

A sizable increase in the quantity of solid waste from air pollution control activities is projected for 1985. Total solid residues are likely to increase from 3,743 x 10^6 kg in 1971 to 6,504 x 10^6 kg in 1985, an increase of 74 percent. Of this total, the largest solid waste contribution will stem from the fertilizer and carbon black sectors, which should together account for 64 percent in 1985. However, other sectors (such as plastics and synthetics, phosphoric acid,and sulfuric acid)are expected to increase their share of total solid residues generated, each showing increases of greater than 100 percent between 1971 and 1985.

Water pollution control and treatment activities in the selected segments of the chemical industry appear to generate a larger quantity of solid wastes relative to air pollution control efforts. In 1971, the various treatment processes applied to suspended solids and dissolved solids in the wastewater generated by the industrial inorganic chemicals sector reached about 3,700 x 10^6 kg of residues. Total solid waste residues from the water treatment programs mentioned above amounted to 9,250 x 10^6 kg in 1971.

In 1985, the total solid waste stemming from water pollution control in the selected sectors of the chemical industry is forecast to increase to 12,940 x 10^6 kg. The contribution of the industrial inorganic chemicals is estimated to be 3,987 x 10^6 kg (a modest increase of 8 percent). Organic chemicals are expected to show a large increase, contributing 817 x 10^6 kg of solid waste, compared to the 1971 level of zero solid wastes generated.

The total sum of solid wastes derived from all air and water pollution control activities in the chemical industry is thus expected to amount to 15,750 x 10^6 kg by 1985. The forecast for solid waste residues may be given a confidence level of 2, indicating a possible ±50 percent variation.

TABLE X-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Sulfuric acid	Total production	Acid mist eliminators & recycle	100	0	95	0	0	0
Phosphoric acid	Thermal process	Packed tower	10	10	100	10	100	10
		Venturi scrubber & recycle	40	(40)	100	(40)	To water treatment	
		Mist eliminator	10	10	100	10	100	10
		Electrostatic precipitator	40	40	100	40	100	40
Plastics	Total production	Misc. controls	75	30	100	30	75	20
Nitrate fertilizers	Total production	Wet cyclones	40	(420)	90	(380)	To water treatment	
		Dry cyclones	25	260	90	240	50	120
		Wet scrubber with cyclones	25	(260)	95	(250)	To water treatment	
		None	10	0	0	0	0	0
Phosphate fertilizer	Total production	Wet acid scrubber	90%	(2,840)	95	(2,700)	To water treatment	
		Fabric filter	10%	320	99	370	50	150

TABLE X-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates: (Cont.)								
Carbon black	Channel process	None	0	0	0	0	0	0
	Gas furnace process	Electrostatic precipitator & baghouse	100	143	90	130	100	130
	Oil furnace process	Electrostatic precipitator & baghouse	100	1,290	90	1,160	100	1,160
		Total		(5,660)	94	(5,300)	31	(1,640)
Sulfur oxides:								
Sulfuric acid	Total production							
		Dry adsorption & alkali scrubber	3	(1,180)	90	(1,060)	To water treatment	
		Total		(1,180)	90	(1,060)	100	(1,060)
Fluorides:								
Phosphoric acid	Wet process	Scrubbers & recycle	50	(40)	90	(40)	To water treatment	
Total Solid Residues from Air Pollution Controls:				2,100	n.a.	1,930	n.a.	1,640

TABLE X-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
NaOH-Cl	Diaphragm cell	Settling ponds	100	80	100	80	100	20
Sodium silicate	Total production	Settling ponds	100	1	95	1	100	1
TiO_2	Chloride method	Settling ponds	50	20	95	20	100	20
		Settling ponds & landfill	50	20	95	20	100	20
Hydrofluoric acid	Total production	Settling ponds	100	1	95	1	0	0
Soda ash	Solvay process	Settling ponds	100	350	95	220	100	320
Sodium metal		Settling ponds	100	1	95	1	100	1
Sodium dichromate	Total production	Settling ponds	100	6	95	6	100	6
Sodium chloride	Solution mining	Isolation of spills	50	3	95	3	100	3
		Partial recycle to brine cavity	50	3	90	3	0	0
SS from air pollution control		Settling ponds	100	4,460	95	4,210	47	1,990
		Total		4,950	95	4,670	63	2,440

TABLE X-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids:								
Sodium silicate	Total production	Neutralization	100	3	95	3	100	3
Sodium metal	Total production	Separation	100	20	95	20	100	20
Soda ash	Solvay process	Evaporation of waste stream	20	1,020	12	122	100	122
		Evaporation & deep well disposal	38	1,950	95	1,850	100	1,850
		Deep well disposal	42	2,150	95	2,040	100	2,040
TiO_2	Sulfate process	Demineralization plus evaporation	100	1,620	95	1,540	100	1,540
	Chloride process	Demineralization plus evaporation	100	40	40	20	100	20
Sodium dichromate	Total production	Evaporation	100	1	95	1	100	1
Sulfuric acid	Total production	Neutralization	100	10	95	10	0	0
Sodium chloride	Solar process	Storage ponds	100	6,470	95	6,150	0	0

TABLE X-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids: (Cont.)								
Hydrofluoric acid	Total production	Neutralization & land dumping	100	neg.	95	neg.	100	neg.
Misc. chemicals	Total production	Misc. controls	75	n.d.				
		Total		13,200	89	11,760	47	5,600
Sludge-dry solids:								
Plastics	Total production	Primary	90	n.d.				
		Secondary	70	n.d.				
BOD_5:								
Organic chemicals	Total production	BPCTA	0	0	0	0	0	0
		None	100	0	0	0	0	0
Total Residues from Water Pollution Controls:				18,230	95	16,430	49	8,040
Total Residues from Air and Water Pollution Controls:				20,330	90	18,360	54	9,680

TABLE X-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Sulfuric acid	Total production	Acid mist eliminators & recycle	100	0	95	0	0	0
Phosphoric acid	Thermal process	Packed tower	10	10	100	10	100	10
		Venturi scrubber	40	(50)	100	(50)	To water treatment	
		Mist eliminator	10	10	100	10	100	10
		Electrostatic precipitator	40	50	100	50	100	50
Plastics	Total production	Misc. controls	75	50	100	50	75	30
		None	25	0				
Nitrate fertilizer	Total production	Wet cyclones	40	(540)	90	(490)	To water treatment	
		Dry cyclones	25	340	90	310	50	150
		Wet scrubber with cyclones	25	(340)	95	(320)	To water treatment	
		None	10	0	0	0	50	0
Phosphate fertilizer	Total production	Wet acid scrubber	90	(3,140)	95	(2,980)	To water treatment	
		Fabric filter	10	350	99	340	100	340

TABLE X-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates: (Cont.)								
Carbon black	Channel process	Electrostatic precipitator plus bag-house	50	10	90	10	100	10
	Gas furnace process	Electrostatic precipitator plus bag-house	100	180	90	160	100	160
	Oil furnace process	Electrostatic precipitator plus bag-house	100	1,380	90	1,240	100	1,240
		Total		(6,450)	93	(6,020)	92	(2,000)
Sulfur oxides:								
Sulfuric acid	Total production	Dry adsorption & alkali scrubber	100	(1,480)	90	(1,330)	To water treatment	
Fluorides:								
Phosphoric acid	Wet process	Scrubbers	50	(50)	90	(40)	To water treatment	
		Total		(1,530)	90	(1,370)	100	(1,370)
Total Residues from Air Pollution Controls:				2,380	n.a.	2,180	n.a.	2,000

TABLE X-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
NaOH–Chlorine	Diaphragm cell	Settling ponds	100	110	100	110	100	110
Sodium silicate	Total production	Settling ponds	100	2	100	2	100	2
TiO_2	Chloride process	Settling ponds plus landfill	100	70	100	70	100	70
Hydrofluoric acid	Total production	Settling ponds	100	2	100	2	0	0
Soda ash	Solvay process	Settling ponds	100	390	100	390	100	390
Sodium metal	Total production	Settling ponds	100	1	100	1	100	1
$Na_2Cr_2O_7$	Total production	Settling ponds	100	6	100	6	100	6
Sodium chloride	Solution mining	Isolation of spills	20	1	100	1	100	1
		Isolation of spills plus recycle to brine cavity	80	6	100	6	0	0

TABLE X-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)								
Suspended solids from air pollution control		Settling ponds	100	5,220	95	4,940	64	3,140
		Total		5,910	95	5,530	67	3,730
Dissolved solids:								
Sodium silicate	Total production	Neutralization	100	3	100	3	100	3
Sodium metal	Total production	Separation	60	10	100	10	100	10
		Return of salts to brine cavity	40	6	100	6	100	6
Soda ash	Solvay	Evaporation	50	2,850	50	1,430	100	1,430
		Evaporation & deep well disposal	50	2,850	100	2,850	100	2,850
TiO_2	Sulfate process	Demineralization plus evaporation	100	1,360	100	1,360	100	1,360
	Chloride process	Demineralization plus evaporation	100	60	100	60	100	60

TABLE X-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids: (Cont.)								
Sodium dichromate	Total production	Evaporation	100	2	100	2	100	2
Sulfuric acid	Total production	Neutralization	100	20	100	17	0	0
Sodium chloride	Solar process	Storage ponds	100	7,000	100	7,000	0	0
Hydrofluoric acid	Total production	Neutralization & land dumping	100	neg.	100	neg.	100	neg.
Misc. chemicals	Total production	Misc. controls						
		Total		14,160	90	12,740	45	5,720
Sludge-dry solids:								
Plastics	Total production	Primary	n.d.	n.d.				
		Secondary	n.d.	n.d.				
BOD_5:								
Organic chemicals		BPCTA	30	160	95	150	100	150
		None	70	0	n.d.	0	0	0
Total Residues from Water Pollution Controls:				20,130	92	18,420	52	9,600
Total Residues from Air and Water Pollution Controls:				22,350	n.d.	20,450	n.d.	11,450

TABLE X-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Sulfuric acid	Total production	Acid mist eliminators & recycle	100	0	100	0	0	0
Phosphoric acid	Thermal process	Packed tower	10	20	100	20	100	20
		Venturi scrubber	40	(70)	100	(70)	To water treatment	
		Mist eliminator	10	20	100	20	100	20
		Electrostatic precipitator	40	70	100	70	100	70
Plastics	Total production	Misc. controls	75	70	100	70	75	50
		None	25					
Nitrate fertilizer	Total production	Wet cyclones	40	(730)	95	(700)	To water treatment	
		Dry cyclones	25	460	95	440	50	220
		Wet scrubber with cyclones	35	(640)	97	(620)	To water treatment	
Phosphate fertilizer	Total production	Wet acid scrubber	90	(3,550)	97	(3,450)	To water treatment	
		Fabric filter	10	400	99	390	50	200

TABLE X-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates: (Cont.)								
Carbon black	Channel process	Electrostatic precipitator plus bag-house	75	20	95	20	100	20
	Gas furnace process	Electrostatic precipitator plus bag-house	100	230	95	220	100	220
	Oil furnace process	Electrostatic precipitator plus bag-house	100	1,480	95	1,410	100	1,410
		Total		(7,760)	97	(7,500)	94	(2,230)
Sulfur oxides:								
Sulfuric acid	Total production	Dry adsorption & alkali scrubber	100	(1,920)	90	(1,730)	To water treatment	
Fluorides:								
Phosphoric acid	Wet process	Scrubbers	75	(100)	90	(90)	To water treatment	
		Total		(160)	90	(140)	100	(140)
Total Residues from Air Pollution Controls:				2,770	n.a.	2,660	n.a.	2,230

TABLE X-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
NaOH-Chlorine	Diaphragm cell	Settling ponds	100	160	100	160	100	160
Sodium silicate	Total production	Settling ponds	50	1	100	1	100	1
		Ponding & clarification	50	1	100	1	100	1
TiO_2	Chloride process	Settling ponds	50	40	100	40	100	40
		Clarifier thickener	50	40	100	40	100	40
Hydrofluoric acid	Total production	Settling ponds	100	2	100	2	0	0
Soda ash	Solvay process	Settling ponds	50	220	100	220	100	220
		Settling ponds plus clarification	50	220	100	220	100	220
Sodium metal	Total production	Settling ponds	100	neg.	100	neg.	100	neg.
$Na_2Cr_2O_7$	Total production	Settling ponds	100	6	100	6	100	6

TABLE X-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)								
Sodium chloride	Solution mining	Isolation of spills & scrubbers	50	4	100	4	100	4
		Partial recycle to brine cavity	50	4	100	4	100	4
Suspended solids from air pollution controls		Settling ponds	100	6,650	100	6,650	50	3,400
		Total		8,180	100	8,180	60	4,930
Dissolved solids:								
Sodium silicate	Total production	Neutralization	80	3	100	3	100	3
		Evaporation	20	neg.	100	neg.	100	neg.
Sodium metal	Total production	Separation & return of salts to brine cavity	100	10	100	10	100	10
Soda ash	Solvay	Evaporation	50	3,180	100	3,180	100	3,180
		Evaporation & deep well disposal	50	2,180	100	2,180	100	3,180

TABLE X-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids: (Cont.)								
TiO_2	Sulfate process	Demineralization plus evaporation	100	1,380	100	1,380	100	1,380
	Chloride process	Demineralization plus evaporation	100	80	100	80	100	80
Sodium dichromate	Total production	Evaporation	100	2	100	2	100	2
Sulfuric acid	Total production	Neutralization	100	20	100	20	0	0
Sodium chloride	Solar process	Storage ponds	100	7,730	100	7,730	0	0
Hydrofluoric acid	Total production	Neutralization	100	neg.	100	neg	100	neg.
Misc. chemicals	Total production	Misc. controls	n.d.	n.d.				
		Total		15,580	100	15,580	50	7,840
Sludge-dry solids:								
Plastics	Total production	Primary	n.d.	n.d.				
		Secondary	n.d.	n.d.				

TABLE X-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
BOD$_5$:								
Organic chemicals		BPCTA	90	600	95	570	100	570
		BPCTA plus BATEA	10	70	98	60	100	60
		Total		670		630		630
Total Residues from Water Pollution Controls:				24,430	100	24,390	55	13,400
Total Residues from Air and Water Pollution Controls:				27,200	99	27,050	58	15,630

TABLE X-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Sulfuric acid	Total production	Acid mist eliminators & recycle	100	0	100	0	0	0
Phosphoric acid	Thermal process	Packed tower	10	20	100	20	100	20
		Venturi scrubber	40	(90)	100	(90)	To water treatment	
		Mist eliminator	10	20	100	20	100	20
		Electrostatic precipitator	40	90	100	90	100	90
Plastics	Total production	Misc. controls	100	130	99	130	75	100
Nitrate fertilizer	Total production	Wet cyclones	25	(610)	97	(590)	To water treatment	
		Dry cyclones	25	610	97	590	50	300
		Wet scrubber with cyclones	50	(1,220)	99	(1,210)	To water treatment	
Phosphate fertilizer	Total production	Wet acid scrubber	90	(4,020)	97	(3,900)	To water treatment	
		Fabric filter	10	450	99	440	100	440

TABLE X-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
Particulates: (Cont.)								
Carbon black	Channel process	Electrostatic precipitator plus bag-house	100	20	95	20	100	20
	Gas furnace process	Electrostatic precipitator plus bag-house	100	290	95	280	100	280
	Oil furnace process	Electrostatic precipitator plus bag-house	100	1,620	95	1,540	100	1,540
		Total		(9,190)	97	(8,920)	96	(8,600)
Sulfur oxides:								
Sulfuric acid	Total production							
		Dry ad-sorption & alkali scrubber	100	(2,440)	95	(2,310)	To water treatment	
		Total		(70)	95	(70)	100	(2,370)

TABLE X-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 28

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Fluorides:								
Phosphoric acid	Wet process	Scrubbers	100	(170)	95	(160)	To water treatment	
Total Residues from Air Pollution Controls:				3,250	n.a.	3,130	n.a.	2,810
WATER POLLUTANTS								
Suspended solids:								
NaOH-chlorine	Diaphragm cell	Settling ponds to evaporation to brine cavity	100	220	100	220	0	0
Sodium silicate	Total production	Settling ponds & clarification	100	2	100	2	100	2
TiO_2	Chloride process	Settling ponds	50	60	100	60	100	60
		Settling ponds plus clarifier-thickener	50	60	100	60	100	60
Hydrofluoric acid	Total production	Settling ponds	100	3	100	3	0	0
Soda ash	Solvay process	Settling ponds plus clarification	100	490	100	490	100	490

TABLE X-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended solids: (Cont.)								
Sodium metal	Total production	Settling ponds	100	neg.	100	neg.	100	neg.
$Na_2Cr_2O_7$	Total production	Settling ponds	100	6	100	6	100	6
Sodium chloride	Solution mining	Isolation of spills: scrubbers	80	7	100	7	100	7
		Partial recycle to brine cavity	20	2	100	2	0	0
Suspended solids from air pollution controls		Settling ponds	100	8,260	100	8,260	55	4,440
		Total		9,110	100	9,110	56	5,069
Dissolved solids:								
Sodium silicate	Total production	Neutralization & evaporation	100	4	100	4	100	4
Sodium metal	Total production	Separation & return of salts to brine cavity	100	8	100	8	100	8

TABLE X-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids: (Cont.)								
Soda ash	Solvay	Evaporation & deep well disposal	100	7,220	100	7,220	100	7,220
TiO_2	Sulfate process	Demineralization plus evaporation	100	1,380	100	1,380	100	1,380
	Chloride process	Demineralization plus evaporation	100	90	100	90	100	90
Sodium dichromate	Total production	Evaporation	100	2	100	2	100	2
Sulfuric acid	Total production	Neutralization	100	30	100	30	0	0
Sodium chloride	Solar process	Storage ponds, evaporation & recovery of metal salts	100	8,540	100	8,540	0	0
Hydrofluoric acid		Lime neutralization & land dumping	100	neg.	100	neg.	100	neg.

TABLE X-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 28

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Dissolved solids: (Cont.)								
Misc. chemicals	Total production	Misc. controls	n.d.	n.d.	n.d.			
		Total		17,270	100	17,270	50	8,700
Sludge-dry solids:								
Plastics	Total production	Primary	n.d.	n.d.				
		Secondary	n.d.	n.d.				
BOD_5:								
Organic chemicals		BPCTA plus BATEA	100	830	98	820	100	820
Total Residues from Water Pollution Controls:				27,210	100	27,210	54	14,590
Total Residues from Air and Water Pollution Controls:				30,460	99	30,340	57	17,400

Factors Affecting the Quality of Data.

The data for air pollution discharge factors are considered to be quite accurate, although they constitute estimates which are representative of the industry as a whole and may not apply to any particular plant. Estimates of water pollution discharge factors are probably less reliable, relating to sample plants which may be less representative of the industry and probably understate its pollutant load. Economic forecasts are on the whole fairly accurate, particularly for the major industrial inorganic chemicals. Projections for the plastics and synthetics sector and for organic chemicals may be subject to a considerable degree of variation, but probably not as much as is likely with fertilizers, whose level of production is subject to uncertainty due to governmental controls and future developments in foreign agricultural markets.

The biggest source of possible error in predicting solid wastes from pollution control in the chemicals industry relates to the estimates of future pollution treatment processes and the resulting solid waste reuse ratios. Different treatment processes with similar efficiencies vary greatly in their impact upon solid waste, and a lack of information concerning reuse ratios exists. Taking the aforementioned factors into account, the overall confidence level for the final estimates of solid residues can be given a confidence level of 2, indicating a ±50 percent possible variation in the data.

Summary.

Untreated Discharges. The chemicals industry generates substantial quantities of both air and water pollutants. Particulates are discharged from the production of carbon black, plastics, nitrate and phosphate fertilizer, and phosphoric acid. Sulfur oxides and hydrogen sulfides are discharged from sulfuric acid and carbon black, respectively. These constitute the major forms of air pollutants which exert significant impact on solid waste residues. The total level of untreated discharges of these air pollutants was forecast to increase from 23.75 billion kg in 1971 to 46.35 billion kg in 1985, an increase of 95 percent. Untreated water pollution discharges in the form of suspended and dissolved solids generated by the manufacture of industrial inorganic chemicals amounted to 15.368 billion kg in 1971 and was projected to increase to 20.899 billion kg in 1985. Untreated sludge from the production of plastics and synthetics and untreated BOD_5 load from the manufacture of organic chemicals were forecast to increase, respectively, from 93×10^6 kg and $3,647 \times 10^6$ kg in 1971 to 324×10^6 kg and $8,336 \times 10^6$ kg in 1985.

Treatment Methods and Reuse. Air pollution control and treatment systems applied in the chemical manufacturing industry tend to utilize mechanical collectors, bag filters, cyclones, electrostatic precipitators, wet and dry scrubbers, and incinerators, either alone or in combination. Recycling of effluents is fairly widespread, notably in sulfuric acid, fertilizer, and plastics manufacturing plants. Most treatment systems utilizing wet scrubbers convert the air pollutants into aqueous wastes which are then channeled into water treatment facilities to emerge as solid waste residues.

Water pollutants are typically subjected to settling and clarification to remove all settleable solids in the effluent prior to being neutralized, evaporated, or lagooned. A considerable proportion of waste residues is recycled or, as in the organic chemicals sector, treated to recover valuable by-products. The solar evaporation method of sodium chloride manufacture is notable for its storage of the "bitterns" solution, composed of brine, for periodic reworking and reuse over long periods. In this fashion, a potentially large source of solid waste residue is eliminated.

Residues Generated from Pollution Control: Types and Amounts. Total solid waste residues resulting from air and water pollution controls in the chemical industry is projected to reach 17,400 x 10^6 kg in 1985, which represents a substantial increase of 80 percent. Residues derived from air pollution control are mainly attributable to fertilizer, carbon black, and sulfuric acid manufacture, while those derived from water pollution control are mainly attributable to inorganic chemicals and plastics, and synthetics manufacture. A notable feature of the predictions is the fact that the advent of more advanced wastewater treatment methods coupled with the projected increase in production levels will cause the organic chemicals industry to contribute 817 x 10^6 kg of solid waste in 1985, as compared to a zero level of solid wastes discharged in 1971. Other sectors, such as carbon black, inorganic chemicals, and fertilizers will exhibit similar, if somewhat reduced, growth patterns in their contribution to solid waste residues.

SECTION XI

PETROLEUM EXTRACTION, REFINING AND TRANSPORTATION

SIC 13, 291

Introduction.

The Petroleum Industry includes Crude Oil and Gas Extraction (SIC 13) and Petroleum Refining (SIC 291). Together these sectors contributed 301 x 10^6 kg of particulate emissions and 3,478 x 10^6 kg of sulfur oxides in 1971. The petroleum industry also generates a large quantity of solid residues in the form of liquid wastes.

There are three main phases in the production of refined end-products by the petroleum industry: drilling (land, coastal, or deep sea); transportation (pipelines and tankers); and refining.

Untreated Discharge Factors.

Air Pollutants. Refinery operations generate large quantities of air pollutants before treatment. The principal air pollutants discharged are particulates, sulfur oxides, and hydrocarbons. Hydrocarbons (i.e., those not included in the estimate for particulate control) do not generate solid wastes when controlled and are therefore not considered in this section.

Table XI-1 lists the primary sources of particulates and sulfur oxides. The method of cracking and the fuel used (oil vs. gas) are the primary factors determining the amounts of air pollutants generated before refining treatment. No significant quantities of air pollutants are generated in the extraction and transportation of crude oil.

Water Pollutants. Table XI-2 lists the major sources of water pollutants for oil extraction and refining. The major pollutants in the oil drilling operations are the "lost" oils caused by spills and leaks and the brines, drilling mud, sludges and natural gas produced, plus a small amount of spent oxidizing water. Oil spills are not quantified in Table XI-2, and are further discussed under water pollutant discharge from transportation.

Salt water brine, usually found in the perimeter of oil and gas reservoirs, presents several problems. To prevent brine water from seeping into the oil, the pumping rate of crude oil is controlled, but frequently the brine is still pumped out along with the oil. The brine is gravity-separated from the oil and treated before it is discharged into deep wells. These oil field brines are usually high in chloride and sodium concentrations (about 6 times higher than in sea water), and are sometimes treated to remove reusable iodine, calcium, potassium, and other salts; the salts are then reclaimed. The salt content of the brine varies in a wide range depending on the area, but as an average it can be estimated to be 100,000 mg/l.[265]

TABLE XI-1

SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE

SIC 13, 291

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Petroleum industry	Composite	m^3 oil	Particulates	0.46[b]	3
	Fluid catylic cracking (FCC)			0.695	273
	Moving bed catylic cracking (MBCC)			0.049	273
	Fluid cooking			1.50	273
	Boiler & process heaters	m^3 oil burned		2.4	273
		m^3 gas burned		0.32	273
	Composite	m^3 oil	SO_x	5.31[b]	3
	FCC	m^3 oil	SO_2	1.41	273
	MBCC	m^3 oil		0.171	273
	Boiler & heaters	m^3 oil burned		19.2 (%S)[c]	273
		m^3 gas burned		32.0 (%S)[c]	273

[a] For 1971 or most recent available information.

[b] Production in the U. S. for 1967 was 3,580 x 10^6 bbl = 569 x 10^6 m^3.[3] 1967 emissions for the U. S. were 87.1 x 10^6 and 1,905 x 10^6 kg per year of particulates and SO_x, respectively, at 67 and 37 percent control respectively. Dividing by the production for 1967 yields discharges before treatment of 0.46 kg/m^3 particulates and 5.31 kg SO_x/m^3 crude oil refined.

[c] Fuel oil sulfur content (% weight) is multiplied by the given constant. Some % factors are based on 100% combustion of sulfur to SO_2 and assumed density of 0.96 kg/liter.[273]

TABLE XI-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 13, 291

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit	Ref. No.
Oil drilling		m^3 oil	Salt (from brine)	200[a]	265
Oil refining	Topping	1,000 m^3 oil	BOD_5	7.1	41
	Low cracking			71.3	
	High cracking			82.7	
	Petrochemical			148.4	
	Lube			184.3	
	Integrated			215.5	
	Topping	1,000 m^3 oil	Oil & grease	5.1	41
	Low cracking			27.4	
	High cracking			31.4	
	Petrochemical			45.6	
	Lube			136.1	
	Integrated			131.8	
	Topping	1,000 m^3 oil	Phenol	0.029	41
	Low cracking			2.85	
	High cracking			5.1	
	Petrochemical			10.3	
	Lube			6.2	
	Integrated			5.1	
	Topping	1,000 m^3 oil	Ammonia	1.43	41
	Low cracking			10.0	
	High cracking			32.8	
	Petrochemical			34.2	
	Lube			22.1	
	Integrated			35.4	
	Topping	1,000 m^3	SS[b]	7.1	b
	Low cracking			19.5	
	High cracking			14.2	
	Petrochemical			43.6	
	Lube			87.5	
	Integrated			52.7	

[a] Concentration of solids (salt) in brine is 100,000 mg/l average; 1 m^3 of oil produces 2 m^3 of brine (or 2,000 l).[265] 1 m^3 of oil will thus produce 200 kg of dry salt.

[b] SS value is computed from the BOD figures listed in Ref. 41 and the ratio of SS to BOD_5 expressed in mg/l in the same report.

The primary causes of pollution from the transportation of crude oil are spillage, leakage and emptying of ballast. The Coast Guard estimates total spills (from vessels, land vehicles, onshore and offshore facilities, pipelines, refineries, storage, etc.) were 71,160 cubic meters in 1972.[267] The major pollutants generated in the refining phase of the petroleum industry are BOD_5, oil and grease, ammonia, phenol, and suspended solids. The main sources of BOD_5 are dewaxing, drying and sweetening, catalytic cracking, and desalting. Processes producing ammonia are distillation, catalytic cracking and desalting. Phenol comes from catalytic cracking, distillation, and drying and sweetening. Suspended solids result mainly from desalting, alkylation, and drying and sweetening. Emulsified oil mostly comes from desalting and distilling.[266]

The discharge data for air pollutants may be given a confidence level of 3, indicating a possible 25 percent variation. The discharge data for water pollutant discharges, which are not as reliable, may be given a confidence level of 2, indicating a possible 50 percent variation.

Industry Description and Schematic.

Figure XI-1 illustrates the major production steps in the petroleum industry. After extraction and transportation, many different final products may be produced. The main purpose of refining is to separate crude oil into gases, gasoline, kerosene, distillates such as diesel fuel, fuel oil, and heavy residuals. (See Figure XI-1.) The petroleum refining operations involve several process steps:[41]

(1) Storage and transportation
(2) Crude desalting
(3) Fractionation
(4) Cracking
(5) Hydrocarbon rebuilding
(6) Hydrocarbon rearrangement
(7) Solvent refining or extraction
(8) Hydrotreating
(9) Grease manufacturing
(10) Asphalt production
(11) Product finishing

The characteristics of the wastewater differ considerably by process.

In the effluent guidelines report for Petroleum Refineries,[41] attempts were made to subcategorize the petroleum refining industry in order to obtain the raw waste load according to the type of the refinery (function) and the process technology employed. This subcategorization is given in Table XI-3.

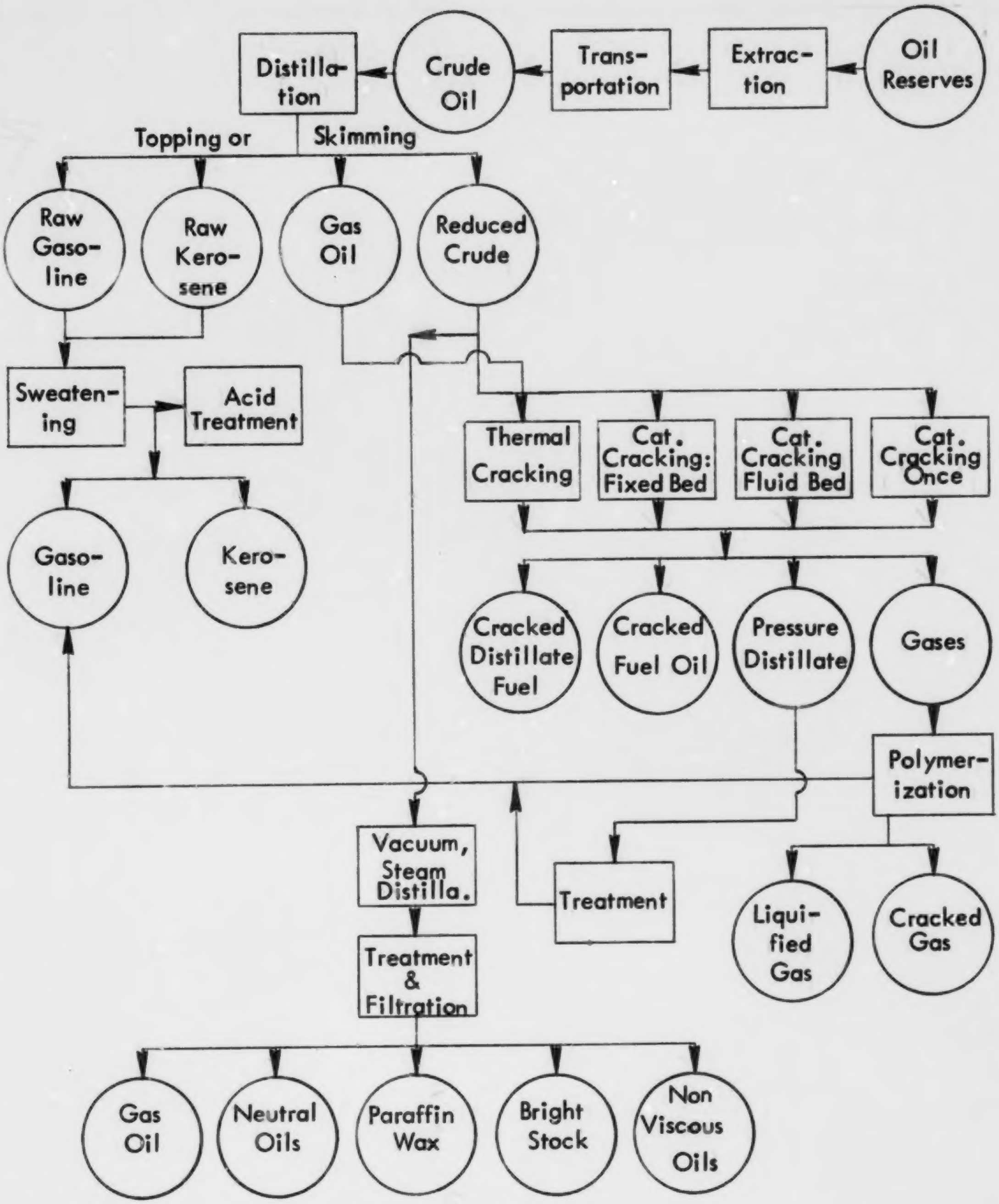

Oil Reserves
Extraction
Transportation
Crude Oil
Distillation
Topping or Skimming
Raw Gasoline
Raw Kerosene
Gas Oil
Reduced Crude
Sweetening
Acid Treatment
Gasoline
Kerosene
Thermal Cracking
Cat. Cracking: Fixed Bed
Cat. Cracking Fluid Bed
Cat. Cracking Once
Cracked Distillate Fuel
Cracked Fuel Oil
Pressure Distillate
Gases
Polymerization
Treatment
Liquified Gas
Cracked Gas
Vacuum, Steam Distilla.
Treatment & Filtration
Gas Oil
Neutral Oils
Paraffin Wax
Bright Stock
Non Viscous Oils

FIGURE XI-1
INDUSTRY SCHEMATIC:
PETROLEUM REFINING
OVERVIEW

TABLE XI-3

SUBCATEGORIZATION OF THE PETROLEUM REFINING INDUSTRY[41]

Subcategory	Basic Refinery Operations Included
Topping	Topping and catalytic reforming.
Low-Cracking	Topping and cracking, with fresh feed (non-recycle) to the cracking and hydroprocessing of less than 50% of the feedstock throughout.
High-Cracking	Topping cracking, with a fresh feed (non-recycle) to the cracking and hydroprocessing of greater than 50% of the feedstock throughout.
Petrochemical	Topping, cracking and petrochemicals operation.[a]
Lube	Topping, cracking and lubes.[b]
Integrated	Topping, cracking, lubes and petrochemicals operation.[a]

---

[a] Petrochemical operations--Production of greater than 15% of the feedstock throughout in first generation petrochemicals and feedstock isomerization products (BTX, olefins, cyclohexane, etc.) and/or production of second generation petrochemicals (cumene alcohols, ketones, etc.).

[b] Lubes--the production less than 12% of the feedstock throughout as lubes. Refineries with greater than 12% lubes are being considered specialty refineries and are handled on an individual basis.

Economic Forecasts.

Growth forecasts for the U. S. oil industry are based on an extrapolation of current trends modified by two principal assumptions; current trends recently published are listed in Table IX-4. The first assumption is that petroleum imports will reach 50 percent of domestic consumption and the second, that 25 percent of imports will be crude oil and the remaining 75 percent will be refined.

Table XI-5 breaks down refining costs and production by refinery category. Table XI-6 presents a forecast of trends in petroleum refining for the years 1971, 1975, 1980, and 1985. Consumption of refined petroleum products is forecast to be 4.13 million cubic meters per day in 1985, 2.58 million cubic meters of which will be domestic. Domestic refinery production is forecast at 940 million cubic meters per year in 1985. If it is assumed that domestic refineries will be operating on an average of 90 percent capacity in 1985, the refining capacity of all refineries will be (2.58)/(0.9) = 2.86 million cubic meters per day (1,044 million cubic meters per year). Of the 940 million cubic meters produced, 753 million cubic meters will be domestic oil. United States refinery capacity is projected to increase from 749 x 10^6 m^3 in 1971 to 1,044 x 10^6 m^3 in 1985 (2.4 percent average annual increase).

The breakdown of production by refinery category in Table XI-6 requires further explanation. Because the best available water pollution data are from the effluent guidelines report for petroleum refineries,[41] the categories used in that report (described in Table XI-3) are the ones forecast in Table XI-6. Although no figure was given for total output by category in the effluent guidelines report, the relative size of these categories can be estimated from cost data cited in the report. Costs per 1,000 cubic meters of oil and costs per year for each category were given; total production per year in cubic meters can be calculated by dividing these two numbers. The resulting outputs in Table XI-5 are far below total refinery production, but can also be used to estimate the percentage breakdown of production. The inaccuracy of the cost figures may have caused the low production output estimates in Table XI-5.

The confidence level for the forecasts in Table XI-6 is 3, indicating a possible 25 percent variation in the data. The largest source of possible error is the currently (1974) uncertain oil import situation and the related energy crisis which tend to cloud any forecast made at the present time.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table XI-7 presents estimated uncontrolled pollutant discharges by the petroleum industry in the forecast years. The forecasts were obtained by multiplying the untreated discharge rates by projected future industry production.

Air Pollutants. Particulates and SO_x are the main air pollutants in this industry. Particulate discharges are forecast to increase from 301 x 10^6 kg to 432 x 10^6 kg over the period 1971 to 1985. Over the same period, SO_x emissions are forecast to increase from 3,478 x 10^6 kg to 4,990 x 10^6 kg.

TABLE XI-4
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 13, 291

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Petroleum refining	Capacity	10^6 m^3/yr			746				375	1972
			1972	760		778			185	1972
			1973	760					397	1973
			1976	812					397	1973
			1970	691		737		1,004	389	1973
			1972	638		754		928	398	1973
		% growth/yr	1973-85	0.8	754				186	1972
	Production	10^6 m^3/yr	1972	673	650				186	1973
			1973	713					186	1973
					655	638	679	679	200	1972
	Total demand	10^6 m^3/yr	1972	952					186	1973
			1973	1,016					186	1973
			1972	911				1,509	189	1973
			1972	934				1,450	396	1973
								1,712	187	1973
			1972	928	859	1,004	1,248	1,422	390	1973
Refined oil products	Consumption	10^6 m^3/yr	1972	940					186	1973
			1973	998	870			1,450	186	1973
									384	1972
	Imports	10^6 m^3/yr	1972	142	130				186	1973
			1973	168					186	1973
			1972	116		151			185	1972
						238			185	1972

TABLE XI-4 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 13, 291

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Petroleum liquids	Imports as % of consumption	% of total	1976	50					422	1973
							50		426	1973
			1973	30					395	1972
			1983	60					395	1972
			1984	66.6					423	1973
			1973	30				50	424	1973
								65	425	1973
Petroleum refinery-capacity in North America	Hydrogen processes	10^6 m^3/yr	1973	381					397	1973
	Catalytic cracking			295						
	Thermal cracking			95						
	Vacuum distillation			330						
				1,100						
	Catalytic reforming			205						
Crude oil	Production	10^6 m^3/yr	1970	656				714	389	1973
			1973	638				865	394	1973
					551	598	644	655	390	1973

TABLE XI-5
CALCULATION OF PERCENTAGE BREAKDOWN OF REFINED PRODUCTS BY REFINERY CATEGORY

Category	BPCTA End of pipe[41] treatment costs ($/1,000 m^3)	BPCTA Annual costs[41] for all plants in category ($/year)	Production per year (10^9 m^3/year)	% of Production
Topping	7.86	14.2×10^6	1.8	1
Low cracking	2.53	35.8×10^6	14.2	10
High cracking	1.84	45.5×10^6	24.7	17
Petrochemical	1.78	53.9×10^6	30.3	21
Lube	1.50	70.1×10^6	46.7	32
Integrated	1.28	35.5×10^6	28.4	19
Totals			146.1	100

TABLE XI-6
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 13, 291

Item	Process or Activity	Physical Units (Metric)	1971 Quantity	1971 Ref. No.	1975 Quantity	1975 Ref. No.	1980 Quantity	1980 Ref. No.	1985 Quantity	1985 Ref. No.
Refinery capacity		$10^6 m^3$/yr.	749	375	800	a	912	a	1,044	a
Domestic refining			655	200	720	a	818	a	940	a
Refining by refinery	Topping (1%)	$10^6 m^3$/yr.	7	b	7	b	8	b	9	b
	Low cracking (10%)		65		72		82		94	
	High cracking (17%)		111		123		139		160	
	Petrochemical (21%)		138		151		172		197	
	Lube (32%)		210		230		262		301	
	Integrated (19%)		124		137		155		179	
Domestic crude production			551	390	598	c	673	c	753	c

TABLE XI-6 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 13, 291

[a] Based on U. S. consumption forecast of 1510 x 10^6 m^3/year in 1985 (an average of currently available figures), with imports contributing 50 percent, and 75 percent of imports in refined form. Production forecast to be approximately 90 percent of capacity.

[b] The breakdown of refinery types was estimated from Ref. 41 by the procedure explained in the text and carried out in Table IX-4.

[c] The 1971 estimate of domestic crude production was obtained from Ref. 390. The remaining forecasts were based on the assumption that U.S. domestic output would equal 50% of consumption in 1985. These forecasts agree in general with the more recent estimates made in References 389, 394, and 424, which include an evaluation of Alaskan reserves, offshore drilling, etc.

TABLE XI-7
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 13, 291

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
AIR POLLUTANTS						
Particulates	All	3	301	331	376	432
SO_x	All	3	3478	3823	4343	4990
WATER POLLUTANTS						
Brine salts	Brine evaporation	265[a]	551	718	942	1130
Crude oil	Oil spills	267[b]	65.5	65.5	65.5	65.5
BOD_5	Topping	41	0.05	0.05	0.08	0.08
	Low cracking		4.7	5.1	5.8	6.07
	High cracking		9.2	10.1	11.5	13.2
	Petrochemical		20.4	22.4	25.5	29.3
	Lube		38.6	42.5	49.1	55.4
	Integrated		26.8	29.5	33.5	38.5
	Total		99.7	109.7	125.4	143.2
Oil and grease	Topping	41	0.03	0.04	0.05	0.05
	Low cracking		1.8	2.0	2.2	2.6
	High cracking		3.5	3.8	4.4	5.0
	Petrochemical		6.3	6.9	7.8	9.0
	Lube		28.5	31.4	35.6	40.9
	Integrated		16.4	18.0	20.5	23.5
	Total		56.5	62.1	70.6	81.1

TABLE XI-7 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 13, 291

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Phenol	Topping	41	0.00019	0.0002	0.00023	0.00027
	Low cracking		0.19	0.20	0.233	0.268
	High cracking		0.57	0.62	0.71	0.82
	Petrochemical		1.4	1.6	1.8	2.0
	Lube		1.3	1.4	1.6	1.9
	Integrated		0.6	0.7	0.8	0.9
	Total		4.1	4.5	5.1	5.9
Ammonia	Topping		0.0094	0.0103	0.01	0.0134
	Low cracking		0.6	0.7	0.82	0.94
	High cracking		3.6	4.0	4.6	5.2
	Petrochemical		4.7	5.2	5.9	6.8
	Lube		4.6	5.1	5.8	6.6
	Integrated		4.4	4.8	5.5	6.3
	Total		18.0	19.8	22.6	25.9

TABLE XI-7 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 13, 291

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Suspended solids[c]	Topping	41	0.046	0.051	0.058	0.0667
	Low cracking		1.3	1.4	1.6	1.8
	High cracking		1.6	1.7	2.0	2.3
	Petrochemical		6.0	6.6	7.5	8.6
	Lube		18.3	20.2	22.9	26.3
	Integrated		6.6	7.2	8.2	9.4
	Total		33.8	37.2	42.2	48.5

---

[a] Based on 0.5% of brine to be evaporated in 1971, 0.6% in 1975, 0.7% in 1980, and 0.75% in 1985.

[b] Oil spills presently discharged 71.2 x 10^3 cubic meters per year.[267] It is assumed that the volume of oil spills will remain about constant.

[c] Suspended solids waste loads are computed from BOD_5 values multiplied by the reported ratio of SS to BOD_5 discharges in petroleum refining.[41]

Water Pollutants. The main water pollutants are brine from drilling, oil from oil spills, and BOD_5, SS, oil and grease, phenol, and ammonia from the refining phase. The brine that accompanies oil extraction is reinjected into the oil wells, except for a small amount used by industry to recover valuable chemicals. This amount is estimated to be about 0.5 percent of the brine produced. As more companies begin recovering chemicals from brine, it is estimated that 0.75 percent of the brine will be used for chemical extraction by 1985.

Oil spills generate various solid pollutants, mainly from various absorbents used in clean-up operations. These absorbents are usually disposed to landfills. The present figure for oil spills given by the U. S. Coast Guard is 71.2 thousand cubic meters per year.[267] It is assumed that increases in the amount of oil transported will be offset by better techniques and safety regulations so that the volume of spills will remain approximately constant. At an estimated average density of 0.92 kg per liter the predicted weight of oil spills will be 65.5 million kg per year through 1985.

Large amounts of BOD_5, oil and grease, ammonia, and suspended solids are generated during petroleum refining; phenols are a lesser problem.

Discharge inventory data for air pollutants may be given a confidence level of 3, indicating a possible 25 percent variation. Discharge data for water, due to greater uncertainty concerning discharge rates, can be given a confidence level of 2, indicating a possible 50 percent variation.

Likely Pollution Treatment Processes.

Air Pollution Control. The major air pollution control processes are illustrated in Figure XI-2. The level of control for particulates was 67 percent in 1967 and has been forecast to increase to 90 percent in 1976.[3] It is estimated that this level of control will increase to 97 percent by 1985. Table XI-8 describes pollution treatment processes used in the petroleum industry. Electrostatic precipitators, which control particulates, have a 97 percent removal efficiency. The control level for SO_x is forecast to increase from 37 percent in 1967 to 62 percent in 1976 and to remain at that level through 1985. SO_x recovery through sulfur recovery plants is 98 percent efficient.

Water Pollution Control. Table XI-8 describes water treatments for pollutants generated during extraction, transportation, and refining of petroleum. The large volume of brine produced as a by-product of crude oil production must be treated and disposed of in such a way as to prevent pollution of water supplies. Pollution can occur through discharge to waterways or through injection into fresh water aquifers. The disposal of brine by evaporation has been attempted. Solar evaporation requires much land and time, while evaporation by heating is very expensive and still leaves the problem of disposing of the concentrated salt residue. Various United States and foreign companies are presently profitably recovering from brine certain marketable minerals such as bromine, calcium, rodine, and potassium. It is assumed that of total salt residues the minerals extracted will increase from 10 percent in 1971 to 15 percent in 1985.

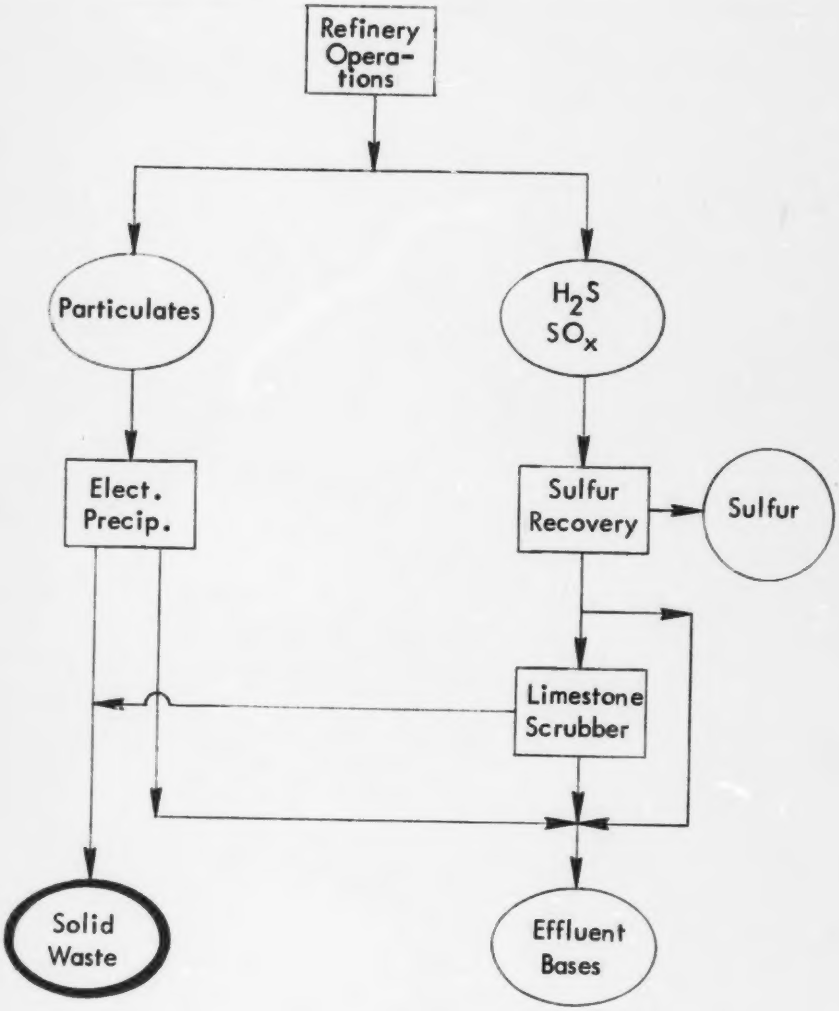

Refinery Operations
Particulates
H_2S SO_x
Elect. Precip.
Sulfur Recovery
Sulfur
Limestone Scrubber
Solid Waste
Effluent Bases

FIGURE XI-2
AIR POLLUTION TREATMENT:
PETROLEUM INDUSTRY

TABLE XI-8

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 13, 291

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
AIR POLLUTANTS							
Petrol. refining		Particulates	Electrost. precipitator	97	1.0		437
		SO_x	Sulfur recovery plant	98	0.5		3
WATER POLLUTANTS							
Brine evaporation		Brine salt	Evaporation		1.00		
Oil spills		Crude oil pick up	Skimming		1.00		267
		Crude oil sorbents	Straw		1.20		267
			Polyurethane		1.01		267
			Other materials		1.10		267
Oil refining		Oil and grease	Gravity separator	60-99	n.d.		41
			Diss. air flotation	70-85			
			Activated sludge	80-99			
			Trickling filter	50-80			
			Aerated lagoon	70-90			
			Oxidation pond	50-90			
		Suspended solids	Gravity separator	10-50	n.d.		41
			Diss. air flotation	50-85			
			Activated sludge	60-85			

TABLE XI -8 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 13,291

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Oil refining (Cont.)		Suspended solids (Cont)					
			Trickling filter	60–85	n.d.		41
			Aerated lagoon	40–65			
			Oxidation pond	20–70			
		BOD_5	Gravity separa.	5–40	n.d.		41
			Diss. air flotation	20–70	n.d.		
			Activated sludge	80–99	0.5		
			Trickling filter	60–85	0.45		
			Aerated lagoon	75–95	0.25		
			Oxidation ponds	40–95	n.d.		
			BPCTA and BATEA		0.5		
		Ammonia	Water stripper	80–95	n.d.		266
			Activated sludge	33–99			41
			Trickling filter	15–90			
			Aerated lagoon	10–45			
			Oxidation ponds	0–15			
		Phenol	Gravity separator	0–50	n.d.		41
			Diss. air flotation	0–50			
			Water stripper	40–75			
			Activated sludge	$95–99^+$			
			Trickling filter	70–98			
			Aerated lagoon	90–99			
			Oxidation pond	60–99			

TABLE XI-8 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 13,291

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Composite sludge volume for refineries		BOD_5	BPCTA and BATEA		0.5		41
			Existing (1974)		0.3		296

The disposal of brine into deep-seated formations seems to be the economical answer to the problem of brine disposal,[265] not only reducing costly brine treatments, but also improving secondary crude recovery, as reinjection helps to flush out more oil. For example, the Arbuckle Formation in Kansas is used for brine disposal and requires no injection pressure. In East Texas, the disposal of brines is performed by subsurface injection. It is estimated in this study that 99.5 percent of the brines are currently (1974) reinjected into deep wells.

Oil spills are controlled by either chemical or mechanical (e.g.,skimming) methods. The skimmer, working like a vacuum, can be used alone or with chemical control methods. Skimmers are used on an estimated 25 percent of all oil spilled. Chemical dispersants, absorbents, sinking agents, and gelling agents are used; floating absorbents are the most common. Most absorbents are oleophilic (oil-attracting) and hydrophobic (water-repelling). Straw and polyurethane, and to a lesser extent other miscellaneous materials, are used as absorbents to clean up oil spills. Straw is widely used due to its availability, low cost, and relative effectiveness. The straw used in oil spills soaks oil equivalent to five times its own weight.[267] Straw is used as an absorbent on an estimated 50 percent of all oil spilled. The oil can be recovered by pressing and then reprocessed, thus reducing the pollutant load. Approximately 60 percent of the oil soaked by straw can be assumed to be recovered in this manner. Residues from straw absorption are thus composed of used straw and the 40 percent of the spilled oil not recovered; the residue is approximately 2 times the weight of the unused straw alone.

Polyurethane, more expensive than straw, can absorb approximately 100 times its own weight and can be continuously reused if reinforced with plastic. It is used on an estimated 20 percent of all oil spilled. By pressing, an estimated 85 percent of the oil spilled is recovered, leaving 15 percent in the sorbent. Thus the weight of the residues from polyurethane absorption is about 16 times the weight of the unused polyurethane.

These remaining sorbent materials, including sawdust, clays, and textile waste, differ widely in composition, weight, and ability to absorb oil. It is estimated that these miscellaneous solvents are used on about 5 percent of all oil spilled. On the average, these materials can absorb ten times their own weight; by pressing, about 30 percent of the oil spilled can be recovered. The remaining 70 percent of the oil, plus approximately 10 percent of the original sorbent, compose the solid residues. The nature of the wasted sorbent varies greatly, from clay materials to wool to sawdust.

When oil spills reach the beach, the oil becomes mixed with sand and soil. Increasingly, these wastes are being cleaned with road graders which separate the oil and sand mixtures for later land disposal.

Biological treatment is the preferred method of treating oily wastewater from refinery operations. Figure XI-3 illustrates the major steps for wastewater treatment in petroleum refining. Biological treatments used include activated sludge (40 percent), trickling filter (10 percent), aerated lagoon (25 percent), and oxidation ponds (25 percent). By extrapolating from 1950-71 data,it has been estimated that by 1985 the breakdown of

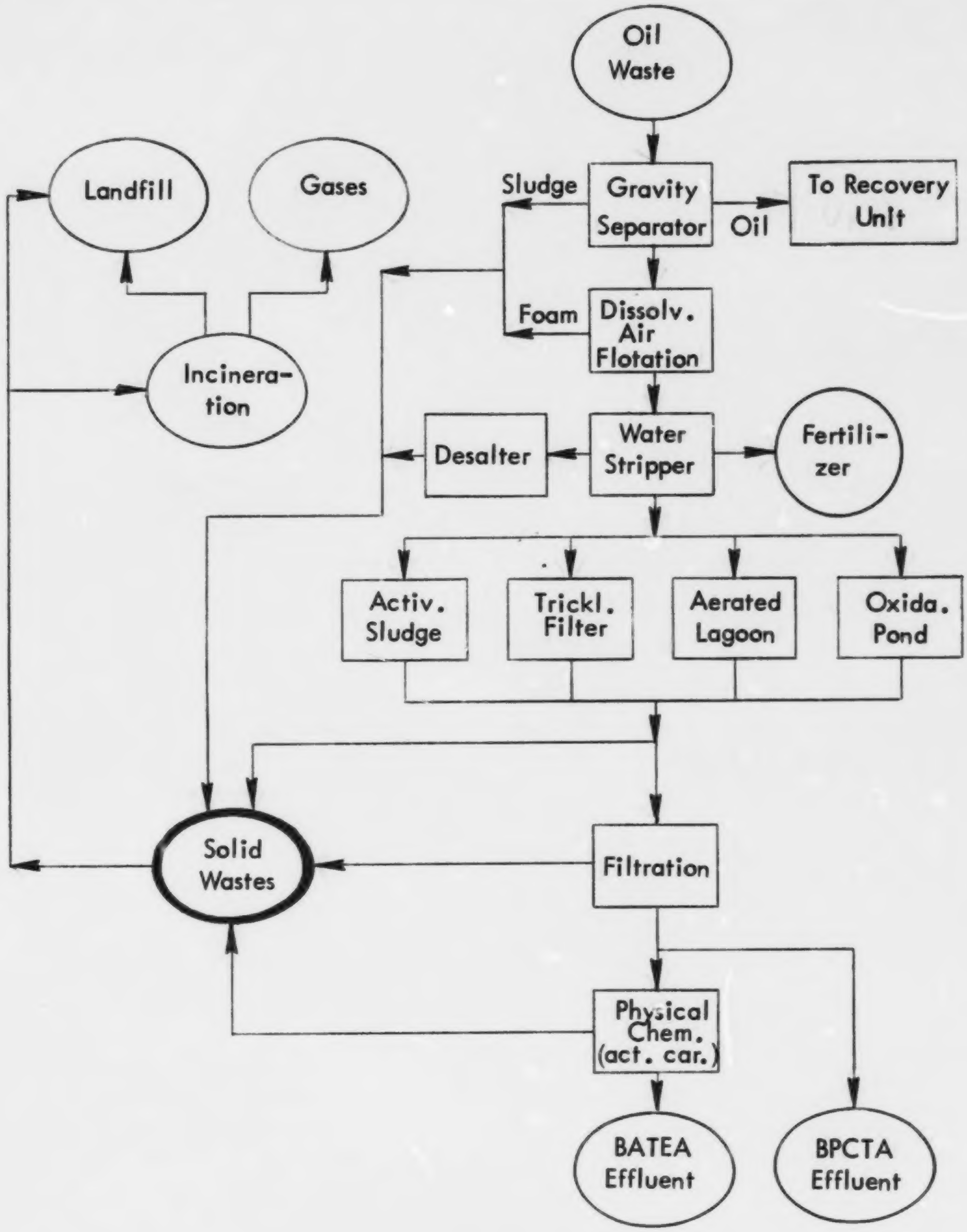

Oil Waste
Landfill
Gases
Sludge
Gravity Separator
To Recovery Unit
Oil
Foam
Dissolv. Air Flotation
Incinera- tion
Desalter
Water Stripper
Fertili- zer
Activ. Sludge
Trickl. Filter
Aerated Lagoon
Oxida. Pond
Solid Wastes
Filtration
Physical Chem. (act. car.)
BATEA Effluent
BPCTA Effluent

FIGURE XI-3
WATER POLLUTION TREATMENT
PROCESS SCHEMATIC:
PETROLEUM REFINERIES

biological treatments will be activated sludge, 60 percent; trickling filters, 10 percent; aerated lagoons, 20 percent; and oxidation ponds, 10 percent. The different ranges in efficiency are given in Table XI-8. Before biological treatment, the effluent requires pretreatment to reduce the content of oil, sulfides (toxic to microorganisms), and phenol. The most frequently used units are gravity separators and dissolved air flotation units for oil removal, and sour water strippers for removal of sulfides, mercaptans and phenol.[266]

Because of the complex nature of the treatment systems which may be employed in refineries, an independent estimate of sludge quantities resulting from water treatment would require empirical testing. To arrive at an estimate of dry sludge solids produced, Table XI-9 first estimates the total raw load of BOD_5 per 1,000 cubic meters of refinery feedstock throughput,[41] and also presents load of BOD_5 per year in thousands of kilograms. BOD_5 is used as the pollutant with which dry sludge solids are estimated. Table XI-10 derives the ratio of dry sludge solids under BPCTA controls to BOD_5 raw waste loads. The range in sludge volume is large for all categories, but this is partially a reflection of different plant size. Sludge quantities arecalculated by dry weight using the estimate that 80 percent of the sludge is water.[41] If the specific gravity of the sludge solids is assumed to be one, then there are 200 kg of dry sludge solids per cubic meter of sludge. A specific gravity of one is a reasonable assumption since the specific gravity of many of the oils and greases is slightly less than one while that of waste media from activated sludge processer is slightly greater than one. The ratios of dry sludge to raw waste load are between 0.4 and 0.64. Since the industry composite waste load is near the middle of the loads cited in Table XI-10, an estimate of 0.5 kg sludge (dry weight) per kg BOD_5 in the raw waste load was established.

The treatment processes required by 1977 (BPCTA) include:[41]

(1) Sour-water strippers to reduce sulfide and ammonia concentrations in the influent to the treatment plant.

(2) Surface condensers or recycling systems with oily-water cooling towers to replace once-through barometric condensers.

(3) Sewer segregation to prevent mixing of unpolluted storm runoff and once-through cooling water with process and the other polluted water.

(4) Elimination of polluted once-through cooling water by monitoring and repair of surface condensers or by use of wet and dry recycle systems.

(5) Extension of commonly used waste treatment practices to the entire industry. These include equalization, clarifiers, dissolved air flotation, and biological treatments such as activated sludge, aerated lagoons, and trickling filters. Some filters may be used following biological treatment.

It is estimated that a 90 percent reduction in the BOD_5 raw waste load will be accomplished by the level of control established with 1977 BPCTA methods. The BPCTA level of control is assumed to be nearly achieved by 1980, with 70 percent of the plants

TABLE XI-9

TYPICAL BOD_5 LOADS FOR SMALL AND LARGE REFINERIES IN INDUSTRY SUBCATEGORIES

Category	kg BOD_5[41] per 1,000m^3 stock throughout	Small Plants		Large Plants	
		Capacity[41] (1,000m^3 feedstock through-out per Day)	BOD_5 per (10^{3}kg)	Capacity[41] (1,000m^3 Feedstock throughout per Day)	BOD_5 per Year (10^3 kg)
Topping	7.1	0.318	0.825	2.4	6.2
Low cracking	71	2.4	62	11.9	308
High cracking	83	4.0	121	23.8	721
Petrochemicals	148	4.0	216	31.8	1,718
Lube	200	4.0	292	39.8	2,905
Integrated	238	9.8	851	49.0	4,257
Industry composite	137[a]				

[a] 99.4×10^6 kg BOD_5 divided by 749×10^6 m^3 refinery capacity from 1971.

TABLE XI-10

RATIOS OF DRY SLUDGE SOLIDS TO BOD_5 IN RAW WASTE LOAD FOR PETROLEUM REFINERIES

Category	Range in Sludge[41] Volume ($10^3 m^3$)	10^3 kg Dry Weight @ 200 kg/m^3 Sludge	Calculated Ratio of Dry Sludge to BOD_5			
			Small Plant		Large Plant	
			BOD_5/year (10^3 kg)	Dry sludge / BOD_5	BOD_5/year (10^3 kg)	Dry sludge / BOD_5 [a]
Topping	2.3 - 15	0.5 - 3	0.875	0.6	6.2	0.5
Low cracking	76 - 380	15 - 76	62	0.24	308	0.25
High cracking	380 - 2,300	76 - 460	121	0.63	721	0.64
Petrochemicals	460 - 3,800	92 - 760	216	0.42	1,718	0.44
Lube	610 - 6,900	122 - 1,380	292	0.42	2,905	0.47
Integrated	760 - 9,200	152 - 1,440	851	0.18	4,257	0.34

[a] Estimated composite ratio of dry sludge to BOD_5: 0.5.

applying these methods, 10 percent meeting the more advanced 1983 (BATEA) standards, and 20 percent achieving only 70 percent treatment efficiency because of variances granted, etc.

The end-of-pipe treatments scheduled to be applied by 1983 (BATEA) include all those used in 1977 plus the addition of activated carbon absorption in fixed-bed columns to the treatment systems proposed as BPCTA technology.

In addition, the use of several in-plant control practices currently practiced in some plants in the industry will further reduce the waste load. These methods include:[41]

(1) Use of air cooling equipment.
(2) Reuse of sour water stripper bottoms in crude desalters.
(3) Reuse of once-through cooling water as make-up to the water treatment plant.
(4) Reuse of boiler condensate as boiler feed water.
(5) Recycling of water from coking operations.
(6) Recycling of waste acids from alkylation units.
(7) Recycling overhead water in water washes.
(8) Reuse of overhead accumulator water in desalters.
(9) Use of dosed compresser and pump cooling water systems.
(10) Reuse of heated water from the vacuum overhead condensers to heat the crude. This reduces the amount of cooling water needed.
(11) Using rain runoff as cooling tower make-up or water treatment plant feed.

The end-of-pipe treatments scheduled to be applied by 1983 (BATEA) involve a reduced waste stream volume and a consequent higher concentration of pollutants in the waste water. The ratio of dry sludge solids to BOD_5 removed is thus approximately the same for BATEA technology as for BPCTA technology. The treatment efficiency is estimated to be 95 percent for BATEA technology, which is assumed to be 90 percent achieved by 1985.

The reduction in wastewater by these methods will improve end-of-pipe treatment at lower cost.

The confidence level for the pollution treatment data in this section is 3, indicating a possible 25 percent variation.

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Table XI-11 lists estimated levels of reuse in the petroleum industry. Sulfur dioxide recovery in a sulfur recovery plant is the only reuse possible of solid waste residues from air pollution control. The efficiency is 98 percent,[3] and estimated level of reuse is 98 percent. The remaining sulfur dioxide escapes in the air, thus creating no solid waste.

All the oil removed in gravity separators is sent to a processing unit for recovery. The grit, suspended solids, etc., are sent in sludge form to landfill disposal or inceneration and ultimate landfill. Ammonia removed in the water stripper unit is used as fertilizer. For example, one large petroleum refinery, in its stripping unit, uses sulfuric acid to react with ammonia in the sour-water stream to create ammonia sulfate, a fertilizer.[296] Another company has a patented treatment process converting waste water into ammonia with over 99 percent purity and hydrogen sulfide with 99.9 percent purity. The latter can be directly used in sulfuric acid plants, and the water after treatment is pure enough for reuse.[265]

Spilled oil can often be recovered and used. For instance, oil absorbed in straw or polyurethane can be pressed out and recovered. Reuse of polyfoam not only reduces pollution from the absorbent but also reduces the cost of oil spill recovery. Multiple reuse is a future possibility if polyfoams are reinforced with plastics.

The reuse data in this section have a confidence level of 2, indicating a possible 50 percent variation in the data.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Total solid waste residues from air and water pollution control from extraction, transportation and refining are forecast to increase from 770 million kg in 1971 to 1,490 million kg in 1985. These figures reflect 48 percent and 62 percent reductions in solid wastes by reuse of solid residues from air and water pollution control in 1971 and 1985, respectively.

No waste products from the control of sulfur oxides are included with the forecast as controls will primarily consist of sulfur recovery plants. If still higher levels of SO_X control are required in the future some limestone scrubbing of sulfur recovery tail gases may be implemented; this would create some solid waste residues in addition to those forecast in Tables XI-12 to XI-15.

Because of the large variation in absorption capacity of the various oil spill sorbents, straw, polyurethane, etc., considerable variation is possible in the amounts of solid waste residues from oil spill clean-ups. Although the trend is away from straw the speed with which straw will be phased out is fairly uncertain.

Particulate treatment is the only air pollution control process which produces solid waste residues. Solid waste residues from particulate control were estimated for 1971 to have

TABLE XI-11
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 13, 291

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
AIR POLLUTANTS					
Refineries					
- particulates		Elect. precipitator	0	3	Dust, particles
- sulfur oxides		Sulfur recovery	100	296	Sulfur-saleable by-product
		Limestone scrubbing	0	296	Calcium sulfates and sulfites, waste limestone
WATER POLLUTANTS					
Extraction - brines		Evaporation	10	a	Salt extracted from brine
Oil spills - crude oil		Skimming	70	296	Oil and water
		Straw	10	b	Absorbed oil and straw
		Polyurethane	30	b	Oil saturated polyurethane foam
		Other materials	30	b	Oil saturated materials
Refineries - oil and grease		Gravity separator	100	266	

[a] This is a rough estimate based on the small market for the minerals which currently exists. By 1985 the percent re-used could possibly climb to 15 percent.

[b] No quantitative estimate is available for the reuse of these materials. Many sources do, however, discuss the possibilities of reuse in the future.

TABLE XI-12
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC 13, 291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Refineries		Elect. precipitator	67	200	97	200	100	200
		None	33	0				
		Total		200	97	200	100	200
Sulfur oxides:								
Refineries		Sulfur recovery	37	640	98	630	0	0
		None	63	0				
		Total		640	98	630	0	0
Total Residues from Air Pollution Control:				840	98	830	13	200
WATER POLLUTANTS								
Brines:								
Extraction		Evaporation	0.5	550	100	550	90	500
		Well injection	99.5	0		0		0
		Total	100	550	100	550	90	500
Crude oil:								
Oil spills		Skimming	25	15	100	15	30	5
		Straw	50	40	100	40	90	35
		Polyurethane	20	15	100	15	70	9
		Others	5	4	100	4	70	3
		Total	100	74	100	74	72	52

TABLE XI-12 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 13, 291

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
BOD$_5$:								
Refineries		1971 treatment	90	25	70	20	100	20
		BPCTA	10	5	90	5	100	5
		Total		30		25	100	25
Total Residues from Water Pollution Control:				660	98	650	88	570
Total Residues from Air and Water Pollution Control:				1,500	98	1,480	52	770

TABLE XI-13
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 13,291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Refineries		Elect. Precipitator	85	280	97	270	100	270
		None	15	0	0			
		Total	100	280	97	270	100	270
Sulfur oxides:								
Refineries		Sulfur recovery	60	1,150	98	1,120	0	0
		None	40	0	0			
		Total	100	1,150	0	1,120	0	0
Total Residues from Air Pollution Control:				1,430	97	1,400	11	270
WATER POLLUTANTS								
Brines:								
Extraction		Evaporation	0.6	720	100	720	89	640
		Well injection	99.4	0			0	
		Total	100.0	720	100	720	89	640
Crude Oil:								
Oil spills		Shimming	25	15	100	15	30	5
		Straw	50	40	100	40	90	35
		Polyurethane	20	10	100	10	70	9
		Others	5	4	100	4	70	3
		Total	100	69	100	69	72	52

TABLE XI-13 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 13, 291

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
BOD_5 :								
Refineries		1971 treatment	70	23	70	16	100	16
		BPCTA	30	16	90	15	100	15
		Total	100	39	79	31	100	31
Total Residues from Water Pollution Control:				830	99	820	84	720
Total Residues from Air and Water Pollution Control:				2,260	98	2,220	29	990

TABLE XI-14
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 13, 291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Refineries		Elect. precipitator	90	340	97	330	100	330
		None	10					
		Total	100	340	97	330	100	330
Sulfur oxides:								
Refineries		Sulfur recovery	62	1,350	98	1,320	0	0
		None	38	0				
		Total	100	1,350	98	1,320		0
Total Residues from Air Pollution Control:				1,680	98	1,650	11	330
WATER POLLUTANTS								
Brines:								
Extraction		Evaporation	0.7	940	100	940	87	820
		Well injection	99.3	0				
		Total	100.0	940	100	940	87	820
Crude oil:								
Oil spills		Shimming	30	20	100	20	30	6
		Straw	40	30	100	30	90	30
		Polyurethane	25	15	100	15	70	10
		Others	5	4	100	4	70	3
		Total	100	69	100	69	68	49

TABLE XI-14 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 13, 291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
BOD_5:								
Refineries		1971 treatment	20	8	70	5	100	5
		BPCTA	70	45	90	40	100	40
		BATEA	10	6	95	6	100	6
		Total	100	59	88	51	100	51
Total Residues from Water Pollution Control:				1,070	99	1,060	84	920
Total Residues from Air and Water Pollution Control:				2,750	98	2,710	30	1,250

TABLE XI-15
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 13, 291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Refineries		Elect. precipitator	100	430	97	420	100	420
		None	0	0				
		Total	100	430	97	420		420
Sulfur oxides:								
Refineries		Sulfur recovery	90	2,250	98	2,200	0	0
		None	10	0				
		Total	0	2,250	98	2,200		0
Total Residues from Air Pollution Control:				2,680	98	2,620	16	420
WATER POLLUTANTS								
Brines:								
Extraction		Evaporation	0.75	1,130	100	1,130	85	960
		Well injection	99.25	0				
		Total	100	1,130	100	1,130	85	960
Crude oil:								
Oil spills		Skimming	35	25	100	25	30	7
		Straw	35	25	100	25	90	25
		Polyurethane	25	15	100	15	70	12
		Others	5	4	100	4	70	3
		Total	100	69	100	69	65	47

TABLE XI-15 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 13, 291

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
$\underline{BOD_5}$								
Refineries		1971 treatment	0	0	70		100	
		BPCTA	10	7	90	6	100	6
		BATEA	90	64	95	61	100	61
		Total	100	71	94	67	100	67
Total Residues from Water Pollution Control:				1,270	99.7	1,270	83	1,070
Total Residues from Air and Water Pollution Control:				3,950	98	3,890	38	1,490

been 195 x 10^6 kg, based on 67 percent treatment of uncontrolled emission and 97 percent treatment efficiency for electrostatic precipitators.[3] Solid waste residues from air pollution control are forecast to increase from 200 x 10^6 to 420 x 10^6 kg from 1971 to 1985, reflecting increased industry output and an increased level of control to 97 percent.

In all years, a large proportion of waste is accounted for by brine disposal, occurring far from urban areas. This brine residue figure is an approximation with an estimated confidence level of 1, indicating a possible 100 percent possible variation in the data; remaining data in this section have a confidence level of 2 (± 50 percent).

Composition of Solid Waste Residues from Pollution Treatment Processes.

The largest weight of solid waste residues generated in the petroleum industry stems from brine disposal. Brines contain approximately 0.1 mg/l of solids.[265] In general, these brines resemble sea water concentrated three-fold. The compositions of sea water and oil filled brines are presented in Table XI-16.

The wastes from oil spill treatment consist mainly of absorbents and oil. The straw used in oil spills soak oil about equivalent to five times its own weight (Table XI-5). This oil can be recovered by pressing and processed, thus creating less pollutant load. The residues from straw absorption are composed of straw and 40 percent soaked oil (3 times the weight of the straw), assuming the remaining 60 percent of the oil is recovered.

Polyurethane can absorb about 100 times its own weight and can be reused continuously if reinforced with plastic. By pressing the polyfoam, an estimated 85 percent of the oil is recovered, leaving 15 percent oil in the sorbent; the weight of sorbent and oil together consistutes about 16 times the weight of the solvent.

The remaining solvent materials differ in composition, weight, and ability to absorb oil. In this group, it is assumed as a whole, the sorbent materials will absorb about 10 times the weight of the sorbent material, and by pressing the solvent only 30 percent of the oil can be recovered. The remaining 70 percent plus 10 percent of the sorbent are residues. The composition of the residues varies greatly from clay materials to wool to sawdust.

Sludges from water pollution control in oil refineries are approximately 80 percent water. Most of the solids are either oil and grease or treatment media. The exact composition of these sludges is difficult to estimate. Rough estimates of composition are presented in Table XI-17.

Factors Affecting Quality of the Data.

There are a large number of alternative process steps in oil extraction, refining, and transportation. The air and water pollutant discharge factors are, therefore, rough estimates. The largest source of error, however, lies in the disposition of solid residues. It was estimated that the brines evaporated would increse slightly from 0.5 percent of all brines in 1971 to 0.75 percent in 1985, with 90 percent of all residues ending up as

TABLE XI-16

COMPARISON OF DISSOLVED SOLIDS IN SEAWATER AND OIL FIELD BRINE

Element	Seawater, mg/l	Oil-field Brine, mg/l
Sodium	10,600	12,000 to 150,000
Potassium	380	30 to 4,000
Lithium	0.2	1 to 50
Rubidium	0.12	0.1 to 7
Cesium	0.0005	0.01 to 3
Calcium	400	1,000 to 120,000
Magnesium	1,300	500 to 25,000
Strontium	8	5 to 5,000
Barium	0.03	0 to 1,000
Chlorine	19,000	20,000 to 250,000
Bromine	65	50 to 5,000
Iodine	0.05	1 to 300

TABLE XI-17

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 291

Item: Refining sludges

Process or Activity:

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	5	41
Volume	l -wet	5	41
H_2O content (of wet weight)	%	80%	41
Combustible	kg	0.5	41
Non-combustible	kg	0.5	41
Ash content	kg	0.5	41
Liquid form	kg		
Solid form	kg		
Energy content	kcal		
Oxygen requirements	kg BOD_5		
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg	0.9	41
Biodegradable	kg		
Non-biodegradable	kg		

wastes in 1971 vs. only 85 percent in 1985. These figures are very rough estimates. The oil spill cleanup methods used in the future may vary considerably from the breakdown in Tables XI-12 to 15, as may the percentage of reuse of the residues from these cleanup techniques. The refinery data are generally the best in this Section, although the ratio of sludge solids to BOD_5 removed may vary by 20 percent or so.

The economic forecasts are fairly accurate but may be affected by the oil import situation. The current (1974) energy crisis casts a shadow of doubt over any forecast of domestic refining. The forecast of solid waste resulting from pollution control in SIC 13 and 791 may be given an overall confidence level of 1, indicating a possible 100 percent or greater variation in the data. Excluding brine wastes (which are generally disposed of in rural areas), the remaining data has a confidence level of 2, indicating a possible 50 percent variation in the data.

Summary.

Untreated Discharges. Oil extraction, transportation and refining contribute significantly to national discharges of both air and water pollutants. The extraction and transportation steps primarily generate water pollutants; refining generates both air and water pollutants. Total uncontrolled particulate emissions from this industry were forecast to increase from 301 million kg in 1971 to 432 million kg in 1985. Sulfur oxides were forecast to increase from 3,478 million kg in 1971 to 4,990 million kg in 1985. Crude oil spills were forecast to remain constant at 65.5 million kg of oil through 1985 as improved technology offsets increased oil drilling and transportation.

Brine salt evaporation was forecast to increase from 551 million kg in 1971 to 1,130 million kg in 1985, although this is a rough estimate.

Refinery operations produce large quantities of BOD_5, oil and grease, phenols, ammonia, suspended solids, and miscellaneous other pollutants. BOD_5 discharges were forecast to increase from 100 million kg in 1971 to 143 million kg in 1985, and suspended solids from 34 to 48 million kg over the same period.

Treatment Methods and Reuse. Refinery particulate emissions are commonly controlled by electrostatic precipitators, although a few baghousees may be used in the future. The solid residue impact of both methods is essentially the same, however, and both create waste requiring disposal. Sulfur oxides and hydrogen sulfide emissions from refineries are normally treated by sulfur recovery processes, generating elemental sulfur. The sulfur is marketable and thus creates no solid waste residues.

The brines which accompany the extraction of oil are normally reinjected into the well, although a small percent (0.5 to 0.75 percent) is evaporated for mineral recovery. Because only 10 to 15 percent of the dry weight can be recovered, this creates solid wastes of 85 to 90 percent of the dry weight evaporated for disposal.

Skimming and absorbents used for oil well clean-ups generate considerable solid waste. Most skimmed oil is recycled, but the remainder is contaminated and must be sent to landfills. Absorbents such as straw and polyurethane may be squeezed to recycle pure oil, but still generate considerable solid wastes.

Water pollutants from refineries are controlled by many in-plant and end-of-pipe treatments. Primary and biological methods achieving a control level of approximately 90 percent are required by the BPCTA technology for 1977 while carbon absorption will be added for 1983 (BATEA) requirements. The sludges from these water treatments are wastes, although some may be incinerated to reduce the solid waste load.

Residues Generated from Pollution Control: Types and Amounts. Total solid waste residues from air and water pollution control in the petroleum industry are forecast to increase from 770 million kg in 1971 to 1,490 million kg in 1985. In all years a large proportion of these wastes will be generated by brine disposal, which is performed near the extraction site and can only be roughly estimated. The mixtures of oil and sorbents from oil spill clean-up are normally sent to landfills and, depending upon the clean-up method used, may contain organic material (straw), plastics, or only oil and water.

Sulfur oxide control makes no significant contribution to solid wastes because of sulfur recovery, while particulate control does contribute wastes. The sludges from refinery operations are 80 percent water and some may be incinerated. Incineration reduces the solids content by half.

SECTION XII
THE CEMENT MANUFACTURING AND STRUCTURAL CLAY INDUSTRIES
SIC 324, 325, 326

Introduction.

The cement and structural clay manufacturing industries are a relatively minor factor affecting United States environmental pollution. Controlled emissions from cement manufacture contribute a negligible amount of pollutants to the environment, with the exception of particulates; the cement manufacturing industry contributes 3.8 percent of the total controlled particulate load released to the air. Emissions prior to treatment are 11.6 percent of total National uncontrolled particulate emissions. This high control level is inherent to the process, since most of the particulates produced are returned to the system for economic reasons in addition to pollution control purposes; this recycling creates no solid residues from pollution control. The structural clay products industry contributes few pollutants to air or water. Emissions are primarily particulates, although in the drying process small quantities of some fluorides and acid gases are also emitted. Uncontrolled particulate emissions are 1.3 percent of the National total. Currently, 22 percent of the clay products plants have no controls, and it is probable that total control will be implemented by 1980.

Untreated Discharge Factors.

Air Pollutants. Of the raw materials fed to the kiln in cement plants, 10-20 percent become airborne and escape as particulates. Particulates are also generated in the grinders and dryers. If uncontrolled, these would result in 9,616 thousand metric tons of particulates; fewer particulates will escape during kiln feeding if the raw materials fed to the kiln are in a slurry. Wet grinding also results in fewer particulates and eliminates the need for drying. Slurry feed and wet grinding are steps in the wet process of cement manufacturing. This process requires more feed water and utilizes more energy, since the kiln must evaporate the water before it can raise the temperature of the materials to the proper level.

Particulates are the main air pollution problem in the clay product industry. They are generated during grinding, screening, blending, mixing, and storage. Drying and firing will give additional gas pollutants if dirty fuels are used. If uncontrolled, particulate emission would be 1.09 million metric tons per year. Particulate emissions can be partially controlled by moisture. The dry method of dust control mostly used is the cyclone process, which removes about 75 percent of the particulates. Table XII-1 presents the estimated uncontrolled air pollution discharge factors in terms of kilograms of pollutant per thousand kilograms of production. The data from which Table XII-1 was developed may be given a confidence level of 2, indicating a possible 50 percent variation.

Water Pollutants. Water used for cement manufacturing becomes contaminated whenever directly in contact with kiln dust. This occurs when the dust is collected but not returned to the kiln. In this case, it is most often disposed of as a slurry, since it is much easier to transport in this form. Direct contact between dust and water also occurs if wet scrubbers are used to remove particulates from stack gases. Cooling water may come into

TABLE XII-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 324, 325, 326

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Cement Products:		kkg	Particulates		169
Kilns	Dry process			123	
	Wet process			100	
Dryers, grinders, etc.	Dry process			48	
	Wet process			16	
Clay Products:		kkg	Particulates		10
Ceramic	Grinding			38	
	Drying			35	
Refractories:					
Kiln fired	Calcining			100	
	Drying			35	
	Grinding			38	
Leachable magnesite				112	
				125	
Mortars	Grinding			38	
	Drying			35	
Mixers				38	
Heavy clay products	Grinding			38	
	Drying			35	

contact rainfall may be contaminated by particulates released to the air. Plant cleanup and transport truck washout provide another opportunity for direct contact between water and particulates. Although contact occurs in the transporting of raw materials to the kiln in the wet process, it is not considered here because this water is evaporated in the kiln and does not constitute a discharge. The most serious instance of water-dust contact occurs if soluble alkali are removed from the kiln dust prior to returning the dust to the kiln. This is accomplished by adding water to the dust to make a slurry and passing the slurry through a clarifier. The normal slurry has about 10 percent solids. Soluble alkali dissolve in the clarifier, and the solids settle to the bottom, resulting in an underflow containing 40 to 60 percent low-alkali solids, which are returned to the kiln. The overflow is discharged. This process is called leaching, and is used if high alkali kiln feed cannot be tolerated. Cement manufacturing plants using the leaching process contribute the highest loading of pollutants within the cement manufacturing industry. Water which has come into direct contact with kiln dust contains abnormally high amounts of aluminum, iron, calcium, manganese, sodium, potassium, sulfate, and chlorides. The presence of these constituents is reflected as TDS, suspended solids, alkalinity, and high pH. Table XII-2 presents the untreated discharge levels of these pollutants, as well as sulfate and potassium. Each listed pollutant has a potential for producing solid waste when treated. It should be mentioned that potassium has a potential for profitable recovery. Potassium sulfate has a market price of $41 per ton. One cement plant reported having recovered 17.5 kg potassium sulfate per ton of cement produced.[260]

Water in the clay industry is used for mixing raw materials before forming the clay, and also in the scrubber to clean from the air the dust created in different production stages. The combination of cyclone and wet scrubber can remove dust with up to 90 percent efficiency. It is assumed that 55 percent of the industry will use wet scrubbers and cyclone, and only 45 percent will use cyclone alone.

Fluoride emission can be reduced substantially by scrubbing the kiln gases with water. This can also serve as a particulate control method. Uncontrolled, average fluoride emission for clay is about 0.61 kg per kkg of clay.

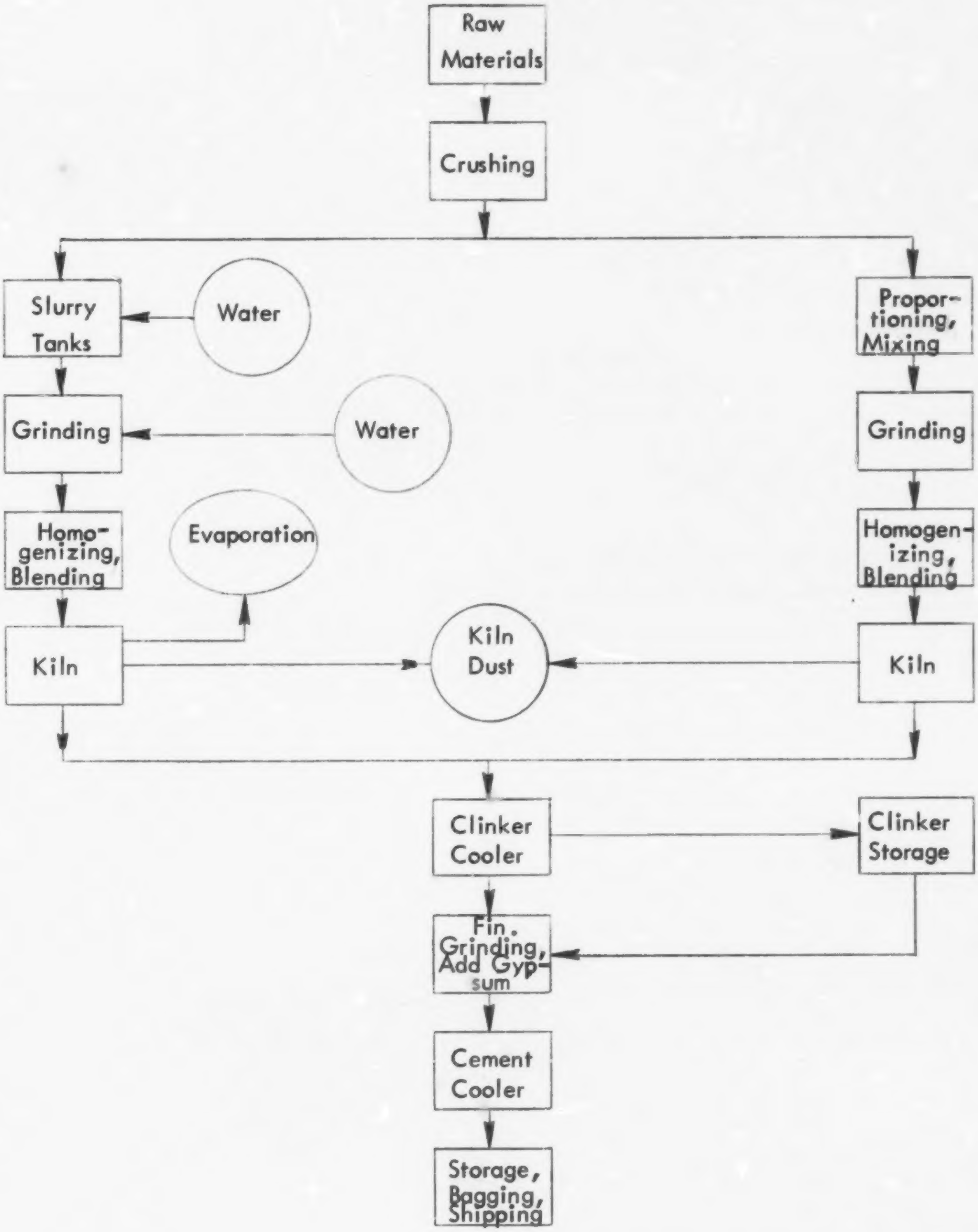
Water pollutant discharge factors for the clay industry are not listed in Table XII-2, since they mostly result from air pollution control (see Table XII-1), and subsequent air-to-water intermedial transfer. The results presented in Table XII-2 have been given a confidence level of 2, indicating a possible 50 percent variance in the data. Uncertainty results primarily from widely-varying practices in the industry of water handling. Many cement manufacturing plants reuse much of their water, some utilize settling ponds and slurry thickeners, and others discharge most of the water they use.

Industry Description and Schematic.

Cement is manufactured by a continuous process, normally interrupted only to reline the kilns. There are three major production steps: raw materials preparation, clinker production, and finish grinding. Figure XII-1 schematizes steps in the manufacture of cement. In the dry process, raw materials preparation requires a drying process,

TABLE XII-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 324

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Cement Products:	Kiln effluent	kkg			260
Leaching plants			TDS	6.6	
Non-leach. plants				0.27	
Leaching plants			Total SS	0.9	
Non-leach. plants				0.0	
Leaching plants			Potassium	3.3	
Non-leach. plants				0.08	
Leaching plants			Sulfate	3.7	
Non- leach. plants				0.0	
Leaching plants			Alkalinity	1.38	
Non-leach. plants				0.09	



Raw Materials
Crushing
Slurry Tanks
Water
Proportioning, Mixing
Grinding
Water
Grinding
Homogenizing, Blending
Evaporation
Homogenizing, Blending
Kiln
Kiln Dust
Kiln
Clinker Cooler
Clinker Storage
Fin. Grinding, Add Gypsum
Cement Cooler
Storage, Bagging, Shipping

FIGURE XII-1
INDUSTRY SCHEMATIC:
CEMENT INDUSTRY

followed by grinding. In the wet process, raw materials are ground with water, resulting in a slurry. Clinker production is the same in both wet and dry processes. The raw materials are passed through a kiln where they are heated to 1,600°C. The wet process requires more kiln time to accomplish evaporation. The resulting output is dry in both processes. Finish grinding is sometimes necessary to achieve the desired uniformity and maximum size of the clinker.

The various processes for handling the dust from this final process, including any leftover kiln dust, have been described previously. In the simplest case, all of the gases are trapped and returned to the kiln for reheating. Very little dust escapes in this method. Twenty percent of cement manufacturing plants report less than 0.005 kg of particulates discharged per kkg of output. In one report, of 80 plants studied, 27 reported an ability to return all the collected dust to the kiln.[250] In other cases, however, all of the collected dust is not suitable for re-kilning and is either removed from the trapped gases by bag filters, wet scrubbing, or some other air cleaning process, or is leached to make it suitable for re-kilning. The amount of removal from dry air-cleaning methods depends on the effectiveness of the particular method. The residues created are usually taken to a landfill. The discharge from leaching or wet scrubbing air-cleaning processes is contaminated water. This water is often reused in the industry. The contaminated water is added to the incoming materials and evaporated in the kiln. Contaminated water from the dry process is usually treated before final discharge. This treatment is normally by settlement ponds or sedimentation tanks.

Production in the clay industry has the following steps: mining the clay and transporting it to the plant, clay preparation (crushing and grinding, screening and separating, and mixing the raw materials), shaping, drying, and firing. Figure XII-2 schematizes steps in clay manufacture. Clays received at the plant are blended to produce a more uniform raw material. The clay is crushed to eliminate large chunks, and then is ground. After grinding, the clay is screened to separate the different sizes. The forming (or shaping) process follows screening. Water and clay are mixed in a mixing chamber (e.g., pugmill) containing two or more revolving blades. Next the clay is molded; excess water is evaporated in dryer kilns at temperatures ranging from 38°C to 200°C for one to two days, depending on the type of clay. Burning is the most specialized step, and requires 40 to 50 hours, depending on kiln type and other factors. Two main kiln types are used: tunnel and periodical. Firing brings the temperature up to 1,300°C. The fuel used can be oil, coal, or natural gas. In periodical kilns, hot kiln gases are permitted to circulate; in tunnel kilns, units are loaded on special cars which pass through different temperature zones as they travel through the tunnel. Drying occurs in the forward section of the kiln, utilizing the heat from the combustion gases to preheat and dry the formed clay as it moves to the firing section. Bricks, for example, require 760 to 1,000 $\times 10^6$ BTU per ton (880 to 1,160 kwh). The cooling period requires 2 to 3 days.

Particulate emissions from the clay products industry are in the form of dust from blending, storage, and grinding operations, and also from off-gases from the tunnel kilns. Particulates from blending, storage, and grinding can be minimized to within emission

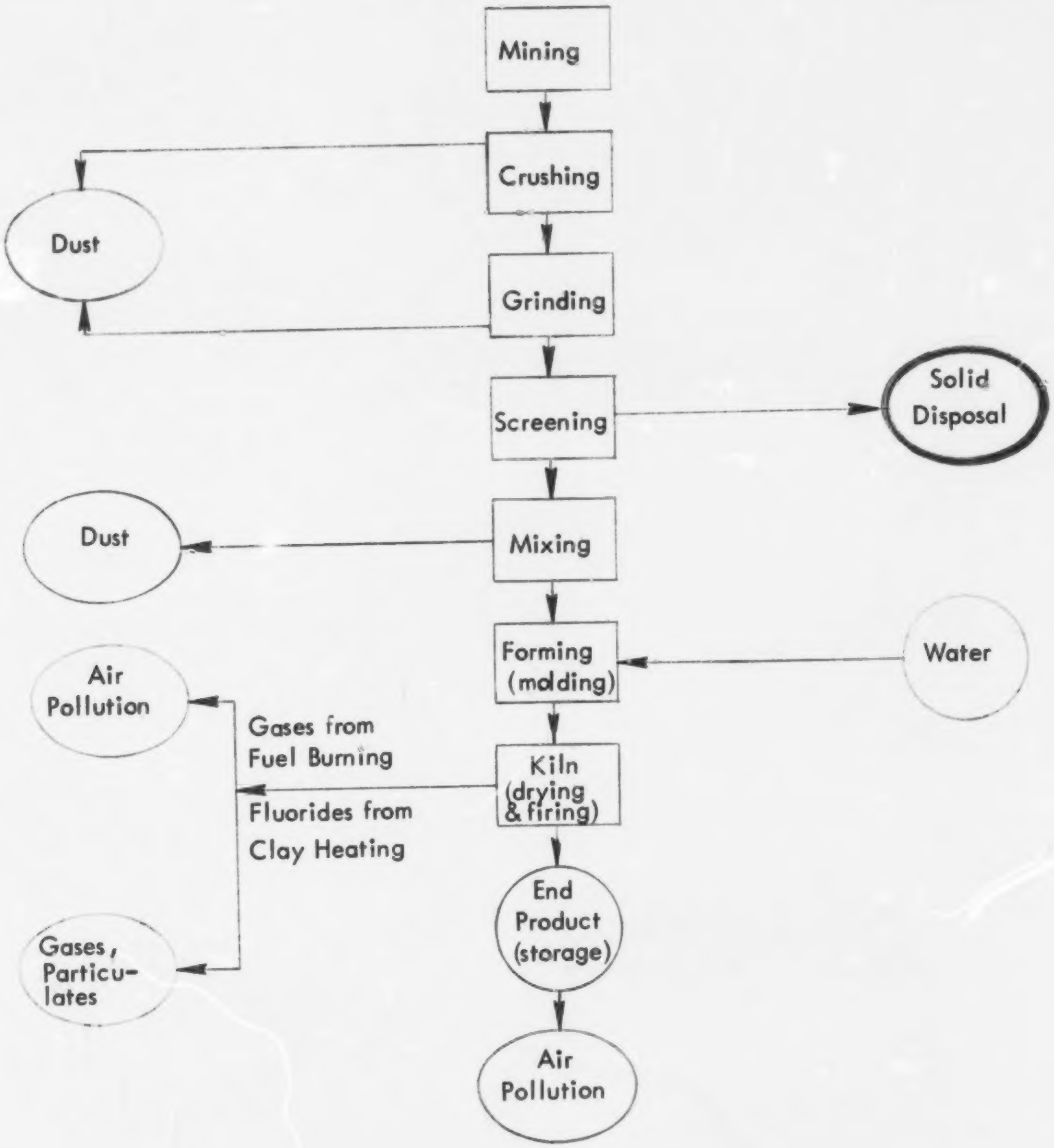

Mining
Crushing
Dust
Grinding
Screening
Solid Disposal
Dust
Mixing
Forming (molding)
Water
Air Pollution
Gases from Fuel Burning
Kiln (drying & firing)
Fluorides from Clay Heating
End Product (storage)
Gases, Particulates
Air Pollution

FIGURE VII-2
INDUSTRY SCHEMATIC:
CLAY PRODUCTS

control standards for particulates by sufficient moisture. Particulate emissions from the kilns depend on the fuel used. For example, SO_2 is emitted if the fuel used contains sulfur or if the firing temperature reaches $1400^\circ C$. Fluorides emitted in a gaseous form result from heating clay containing fluorides. Most of the fuel used has an acceptable sulfur content and the emission of SO_2 is considered negligible.

Economic Forecasts.

The demand for cement is a derived demand. It is affected by the pattern of demand in major construction industries. A building boom has existed for several years in housing and in some types of non-residential construction, including electric power, commercial, hospital, and conservation. Although some reduction is expected in residential construction, non-residential construction should continue to increase. In light of expected aggregate income increases, and due to a lack of sufficient forecasting for the industry, it is estimated that cement production will show a 3 percent growth rate for the period 1971-1985.

The wet process is used at the present time in 58.4 percent of the cement manufacturing industry, the dry process in the remaining 41.6 percent. Both processes are compatible with the likely effluent guidelines that will exist in the future. Discharge treatment methodologies are capable of achieving virtual zero discharge for both processes. The relative growth rates for the two processes will, therefore, be determined by traditional factors. Geography has been a major factor in the determination of the relative suitability of the two processes because plant location determines the type of raw materials readily available; the availability of water; the prevailing ambient temperature, humidity, and precipitation; and local market needs. Historical trends will also influence the relative growth rates for the two processes; companies which have primarily used one process will tend to adopt the same process in new plants. Based on these factors, it is assumed that relative growth in the two processes will remain constant.

The clay products industry has been growing slower than the building industry. The brick and tile industry, for example, grew at onlya 2.8 percent rate over the 1958-67 period while the building industry grew at a 5.3 percent rate during the same period. This is partly due to price competition from other building materials. Competition is based on cost in-place: cost of the material plus installation costs. The cost of brick has increased faster than the cost of other construction materials (22 percent versus 17 percent) and the labor cost of installation has increased rapidly (it currently accounts for 75 percent of in-place costs). The industry, especially marginal firms, will face additional economic problems when required to install pollution control equipment. Higher brick prices will encourage substitution of other building materials for brick. It is predicted that many marginal producers will be forced to merge or cease operations.

Table XII-3 presents a summary of available economic forecasts for both the cement and clay industries. Table XII-4 presents predicted industrial production for the years of 1971, 1975, 1980, and 1985. For the cement industry, a three percent growth rate

TABLE XII-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 324,325,326

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Cement Products:		10^6 kkg								
Capacity	All		1967	85.6					89	1972
			1977	97.5						
	Clinker		1970	75.8	77.8				213	1972
	Grinder				85					
Production	All		1972	78.0	77.1				216	1972
			1976	79			85		220	1972
			1972	73		81	90		218	1972
			1977	85			93		217	1972
					70.0				213	1972
	Clinker				68.3				213	1972
	Grinder				70.0				213	1972
	Shipments		1972	75.0	71.6	84.4	97.2	108.4	68	1973
			1977	85.0	71.5	93.4			214	1972
	Demand				71.5		85.5		215	1973
Imports			1970	2.4	2.8				213	1972
			1972	4.4		9			219	1973
						15			219	1973

TABLE XII-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 324,325,326

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Clay Products:		10^6 kkg							10	1969
Ceramic	Grinding		1968	4.28						
	Drying			7.14						
Refractories	Calcining		1968	0.624						
-kiln fired	Drying			0.936						
	Grinding			3.121						
	-Castable		1968	0.499						
	-Magnesite			0.109						
-mortars	Grinding			0.109						
	Drying		1968	0.109						
-mixes				0.226						
Heavy clay	Grinding		1968	4.301						
products	Drying			6.452						

TABLE XII-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 324,325,326

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Cement Products:	All production	10^6 kkg	70.0	213	78.8	a	89.9	a	104.2	a
	Wet process		40.8	3	46.0	b	52.4	b	60.8	b
	Dry process		29.1	3	32.8	b	37.4	b	43.4	b
Clay Products:		10^6 kkg		c		c		c		c
Ceramic	Grinding		4.65		5.19		5.96		6.84	
	Drying		7.75		8.66		9.94		11.4	
Refractories –kiln fired	Calcining		0.68		0.76		0.87		1.00	
	Drying		1.01		1.13		1.29		1.49	
	Grinding		3.39		3.78		4.35		4.99	
-castable			0.54		0.60		0.69		0.80	
-magnesite			0.118		0.13		0.15		0.17	
-mortars	Grinding		0.118		0.13		0.15		0.17	
	Drying		0.118		0.13		0.15		0.17	
-mixes			0.24		0.27		0.31		0.36	
Heavy clay products	Grinding		4.67		5.21		5.98		6.87	
	Drying		7.01		7.83		8.94		10.26	

TABLE XII-4 (Cont.)

COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 324,325,326

a. The 1971 estimate of total domestic ground cement is obtained from Ref. 213. Forecast estimates for 1975, 1980, and 1985 obtained via an assumed 3 percent annual compound growth rate. This growth rate is based on an averaging of existing production growth rate forecasts contained in Refs. 213,214,215.

b. The 1971 estimate of cement production by wet and dry processes obtained from Ref. 3 is assumed on the basis of information presented in Ref. 3, that the process mix of portland cement production will be constant up to 1985. Thus, the wet and dry processes will account for 58.4 and 41.6 percent of total production, respectively.

c. The 1971 estimates and future projections are based on extrapolating 1968 estimates contained in Ref. 10, using a compound annual growth rate of 2.8 percent. This growth rate is presented in Ref. 3 as the expected annual growth rate of SIC 3251 for the period 1967-1976.

overall and a constant ratio of production between wet and dry processes are assumed. For clay production, an annual growth rate of 2.8 percent is assumed.[3] These assumptions are reasonable, and the economic forecast data can be given a high confidence level of 4, indicating a ± 10 percent possible variation in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Waste. Table XII-5 presents forecasts through 1985 of total air and water pollutant discharges prior to treatment generated by the cement manufacturing and clay products industries. The untreated discharge factors in Tables XII-1 and XII-2 were multiplied by the production forecasts in Table XII-4 to obtain the figures shown. The confidence level for the total untreated air and water pollutant discharge factors in Table XII-5 is 2, due mainly to marginal confidence in the untreated discharge factors; this level indicates a possible 50 percent variance in the data.

Likely Pollution Treatment Processes.

Efficiency levels of the various air and water pollution treatment methods are presented in Table XII-6. The efficiencies of these treatment processes can be estimated with reasonable accuracy from past performance. These efficiency estimates are, therefore, given a confidence level of 4, indicating a possible 10 percent variance in the data.

Air Pollution Control. The removal of particulates from air streams is a well-developed process. Twenty percent of cement manufacturing plants are presently producing less than 0.005 kilograms of particulates per metric ton of product. This corresponds to approximately 1 milligram of particulates per liter of emitted gas. Particulate removal in the clay products industry is done with a cyclone (dry process) or cyclone combined with water scrubber (wet process). The cyclone process is assumed to remove an average of about 75 percent and the wet process about 90 percent of the particulates.[169] Other treatments are possible, such as paper and fabric filters, inertial separators, gravity settling chambers, and electrostatic precipitators, but cyclones and scrubbers are the most used because they operate relatively trouble-free, are durable, and are inexpensive to operate. The efficiency of a cyclone depends on particle size and can be 95 to 99 percent efficient if particle size is at least 40 microns, but only 50 percent if the particle size is 5 microns or less.[23] The scrubber efficiency depends on scrubbing ratio (liter per cu m), gas velocity in the scrubber, contact time, contaminant, etc. If more removal is needed, electrostatic precipitators can be used but costs and electricity requirements are much higher. Precipitator efficiency can reach 99 percent or more, depending on the equipment.

Table XII-6 presents the expected efficiencies of the various combinations of precipitators, cyclones, and fabric filters. Insufficient data and the profitability of kiln dust reuse made an estimate of cost ranges impossible. It has been estimated that an industry-wide application of an improved dust recovery system would result in a savings of $165,000 per year.

TABLE XII-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 324,325,326

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Cement Products:						
Suspended solids	Leaching	260	12	15	15	19
	Non-leaching		0.0	0.0	0.0	0.0
TDS	Leaching	260	93	104	119	138
	Non-leaching		15	17	19	23
Sulfate	Leaching	260	52	58	66	77
	Non-leaching		0.0	0.0	0.0	0.0
Potassium	Leaching	260	46	52	59	69
	Non-leaching		5	5	5	6
Alkalinity	Leaching	260	19	22	24	29
	Non-leaching		5	5	6	7
Particulates	Dry kiln	169	3,584	4,028	4,560	5,334
	Dry grinder, etc.		1,397	1,569	1,796	2,077
	Wet kiln		4,083	4,560	5,244	6,079
	Wet grinder, etc.		653	736	839	971
	Total		9,717	10,893	12,439	14,461

TABLE XII-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF
POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 324,325,326

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Clay Products:		10				
Particulates	Ceramic-grind		177	197	226	260
	-dry		271	303	348	399
	Kiln-fired-calcine		68	76	87	100
	-dry		35.3	39.6	45.1	52.1
	-grind		129	143	165	190
	Refractories					
	-castable		60.5	67.2	77.3	89.6
	-magnesite		14.7	16.2	18.7	21.2
	-mortars, grind		4.5	4.9	5.7	6.5
	-mortars, dry		4.1	4.5	5.2	6.0
	-mixes		9.1	10.3	11.8	13.7
	Heavy clay prod.					
	-grind		177	198	227	261
	-dry		245	274	313	359
Total			1,195	1,334	1,530	1,758

TABLE XII-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 324, 325,326

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Clay Products:							
Kiln;dryers, grinders, etc.		Particulates	Multicyclones	80	1		169
			Old electrostatic precipitators	90	1		
			Multicyclones & old electrostatic precipitators	95	1		
			Multicyclones & new electrostatic precipitators	99	1		
			Fabric filter	99.5	1		
Dust handling	Wet scrubber; leaching	SS	Lagoons	50-80	1		260
			Reuse	99	1		
			Carbonation & advanced sedimentation	99	1		

TABLE XII-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 324,325,326

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Cooling water		TDS	Reuse	94	1		260
Process water	All	TDS	Complete reuse	99	1	0 .05	
		Sulfate	Coagulation + lagoons	50-80	1		
		Potassium	Coagulation + lagoons	50-80	1		
		Alkalinity	Neutralization	70-80	n.d.		
			Carbonation	99	1.3		
Clay Products:		Particulates					
Drying Grinding Storage			Cyclone	75	1		169
Drying Grinding Storage		Particulates	Multiple unit cyclone, scrubber	90	1		169
Scrubber effluent			Settling ponds		1		

Water Pollution Control. Direct water pollutants are generated by the cement manufacture industry, but not the clay manufacture industry. There are two categories of water pollution control methods in the cement industry. One is applicable to cement plants which do not practice leaching and the other to plants which do. Likely water pollution treatment processes for the cement industry are described in Table XII-6.

Non-leaching plants can achieve 99 percent efficiency by the controlled recycling and reuse of water. This requires several operations:

1. Recycling cooling water through the use of cooling towers or similar methods, through isolating cooling water from possible contamination, or through the reuse of cooling water for slurry preparation in plants utilizing wet feed.

2. Containment and recycling of slurry water washovers and spills in plants utilizing wet feed.

3. Installation of dikes wherever run-off of contamined water is possible, such as kiln dust piles and sedimentation ponds. These dikes should be of sufficient magnitude to prevent run-off in the event of a rainfall equivalent to the largest historical rainfall occuring in a 24-hour period over the last ten years.

4. Recycling or evaporation of water used to slurry waste dust. This technology reportedly would result in a 99 percent reduction in pollutants. The investment cost for a typical plant (520,000 kkg per year) would be approximately $200,000 and operating cost about $27,000 per year. This would result in a cost per metric ton unit of $0.05, as reported in Table XII-6.

Cement plants utilizing the leaching process for the removal of alkali from kiln dust pose a more difficult treatment problem. The leachate stream must be segregated from other water streams. These other water streams may be recycled as in a non-leaching plant. The leachate stream, to meet effluent guidelines, would probably require treatment by a combination of carbon dioxide scrubbing and sedimentation. In this methodology, the stack gases, which have a high content of carbon dioxide, are bubbled through the leachate stream. The CO_2 reacts with calcium hydroxide ($CaOH_2$) to form calcium carbonate ($CaCO_3$). The suspended solids, which now are primarily calcium carbonate, are removed by sedimentation in a clarifier. The resultant water has only 0.15 kg of suspended solids per metric ton of dust leached. The initial investment for scrubbing and sedimentation facilities is about $225,000. No data are available on additional operating costs, but the average increased operating costs for the cement industry due to all pollution control treatment equipment necessary to meet proposed 1977 effluent guidelines is estimated to be $0.11 per metric ton.

Cement plants utilizing the dry process do not have an opportunity to reuse wastewater in the preparation of feed slurries, since they require dry feed. Water recycled in the total reuse methodology described above will have to be treated by the same facilities described for treatment of the leachate stream.

Treatment Process Schematics. Figures XII-3 through XII-5 schematize air and water pollution treatment processes. Disposal alternatives for solid residues created by pollution treatment processes are also described. Kiln dust may be returned to the kiln directly, disposed of in landfills, or mixed with water. Scrubbers create waterborne residues directly. Suspended solids usually are thickened in a leaching basin. The overflow is sent to a settling pond and the underflow may be returned to the kiln. The effluent from water treatment processes may be neutralized before discharge to waterways.

Reuse Potential for Solid Waste Residues of Pollution Treatment Processes.

The reuse potentials for residues produced by pollution treatment processes in the cement products industry is presented in Table XII-7. Most of these reuses have been discussed. The kiln dust reuse figure is the least predictable quantity on an industry-wide basis. This figure varies widely depending on the type of dust collection process used.

Table XII-7 also presents reuse potentials for the clay products industry. The dust collected from the cyclone is assumed to be totally reused in the mixing process. This means that all of the 75 percent collected from the cyclone is reused and the remaining 25 percent escapes to the air or receives additional treatment. A multiple-unit dust collection process (cyclone and scrubber) produces dry waste and wastewater rich in dust and particulates. The efficiency of the cyclone and scrubber combination is 90 percent. 75 percent of the dust entering the unit is caught by the cyclone (all of which is reused), 15 percent becomes liquid waste, and the remaining 10 percent escapes in the air. The reuse percentage is lower for the multiple unit because the 15 percent of total dust entering the unit which becomes liquid waste is not reused. Table XII-7 has been given a confidence level of 3, indicating a possible 25 percent variation in the data.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Estimates of solid waste residues from air and water pollution control for the cement and clay product industries are presented in Tables XII-8 through XII-11. The estimated percent of pollutants treated by particular processes was based on the relative costs and treatment efficiencies of the various processes. In some cases, two or more processes may be virtually equivalent in treatment efficiency and cost. Various plants will choose among these processes according to the relative ease of incorporating the process into the plant. The ultimate treatment means used to construct Tables XII-8 to XII-11 was then divided among the processes, as, for example, in fabric filters versus new electric precipitators. It is assumed that ultimate particulate treatment will be divided equally between these two processes.

For cement manufacture, particulates controlled by wet scrubbing are transferred to water as suspended solids. It is assumed that throughout the forecast period one-third of the plants utilizing the wet scrubbing process will also utilize leaching. The available data on the discharges resulting from leaching include the discharges resulting from the leaching of the wet scrubbing discharge. To avoid counting the wet scrubbing

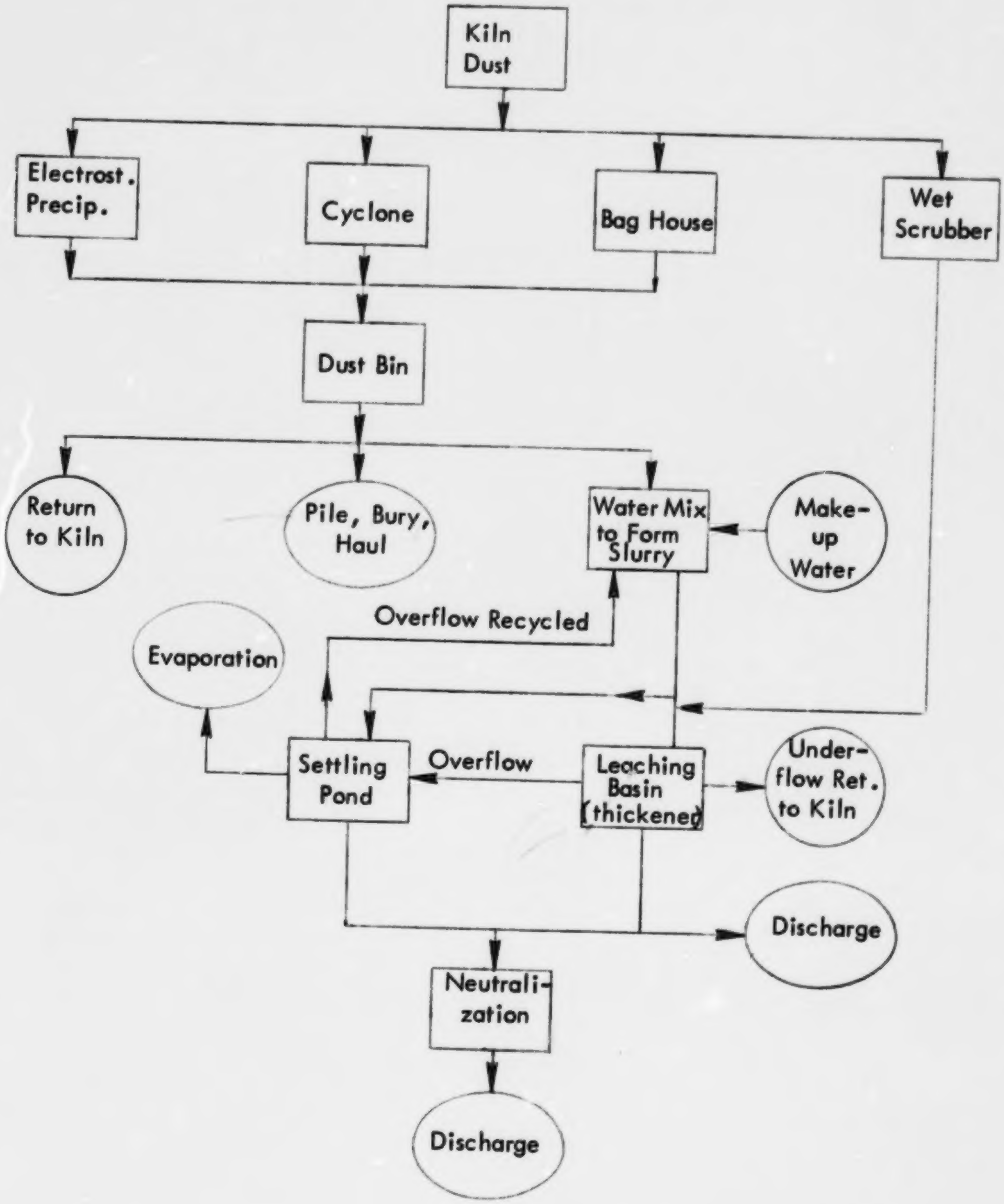

Kiln Dust
Electrost. Precip.
Cyclone
Bag House
Wet Scrubber
Dust Bin
Return to Kiln
Pile, Bury, Haul
Water Mix to Form Slurry
Make-up Water
Overflow Recycled
Evaporation
Settling Pond
Overflow
Leaching Basin (thickener)
Under-flow Ret. to Kiln
Discharge
Neutralization
Discharge

FIGURE XII-3
AIR POLLUTION TREATMENT
PROCESS SCHEMATIC:
CEMENT INDUSTRY

XII-20

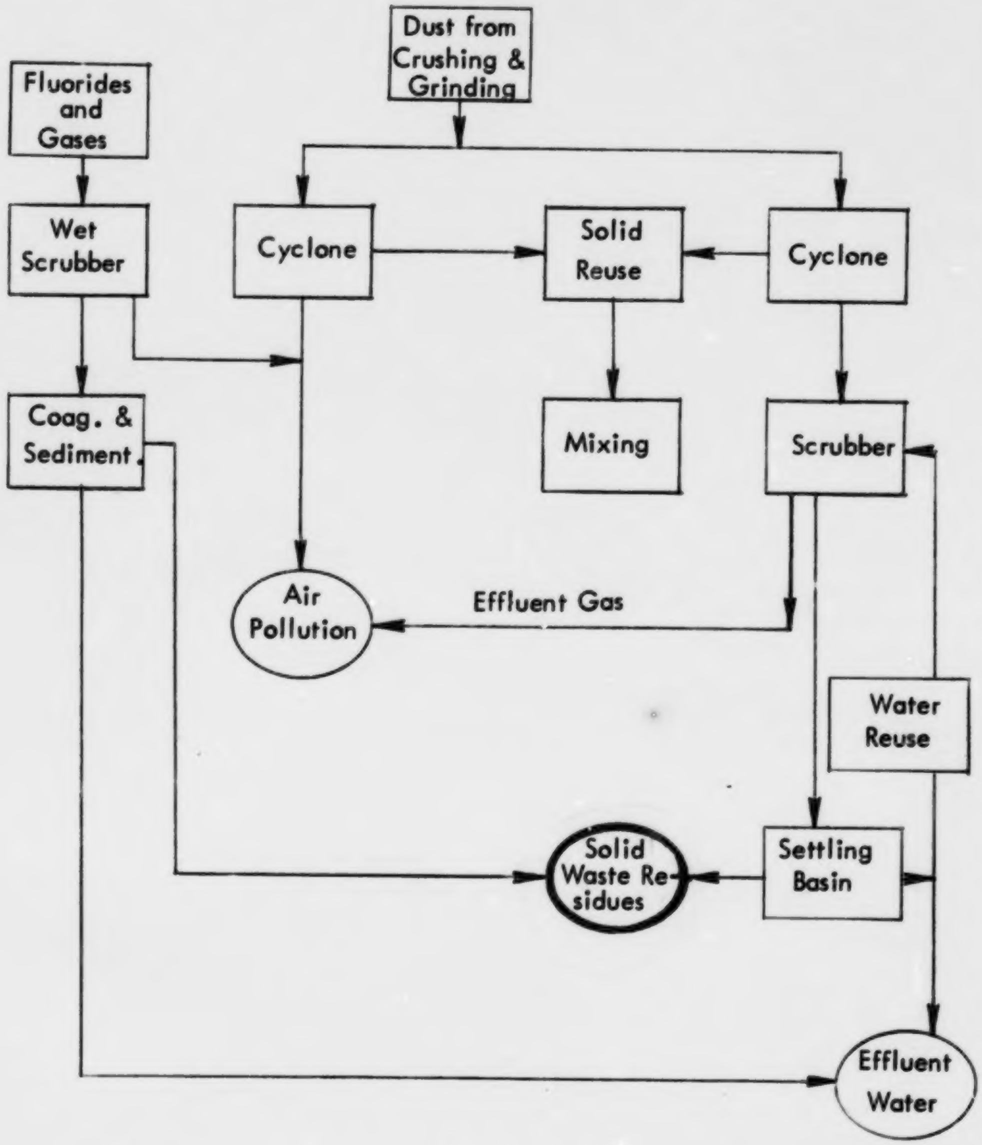

Dust from Crushing & Grinding
Fluorides and Gases
Wet Scrubber
Cyclone
Solid Reuse
Cyclone
Coag. & Sediment.
Mixing
Scrubber
Air Pollution
Effluent Gas
Water Reuse
Solid Waste Residues
Settling Basin
Effluent Water

FIGURE XII-4
WATER POLLUTION
TREATMENT PROCESS SCHEMATIC:
CLAY PRODUCTS

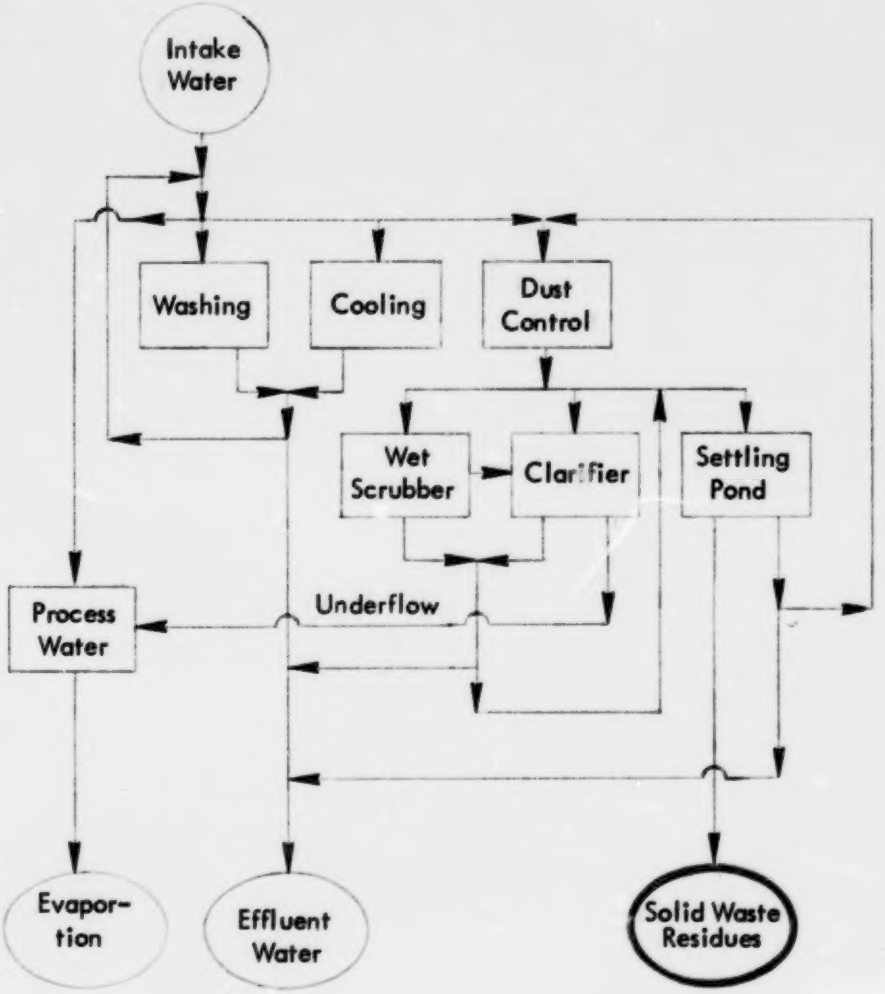

Intake Water
Washing
Cooling
Dust Control
Wet Scrubber
Clarifier
Settling Pond
Process Water
Underflow
Evapor-tion
Effluent Water
Solid Waste Residues

FIGURE XII-5
WATER POLLUTION TREATMENT
PROCESS SCHEMATIC:
CEMENT INDUSTRY

TABLE XII-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 324,325,326

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Cement Products:				260	
All water reuse	Baghouse & precipitator	Recycle	99		Bleed water
Kiln dust	Electrostatic precipitator	Electrostatic precipiators	0		Kiln dust used for fill or discarded
	Cyclone collection	Sump	0		Waste used as surface piling
	Baghouse	Recycle of dust	70-100		Kiln dust 15 kg/ton to quarry
	Multi-cyclone	Return to kiln	100		Kiln dust
Dust-slurry	Electrostatic precipitator	Lagoons	0		Solid dust used as sub-base fill
Leachate	Cyclone precipitator	Clarifier	≈100		SS of 40 mg/l from clarifier to river
Wet scrubber effluent	Scrubber	Stack gases, clarifiers	Most		
Potassium-sulfate	Evaporator	Recovery	10		Worth $37/kkg
Clay Products:				169	
Particulates		Cyclone	100		None
		Multi-unit cyclone & scrubber	83		Liquid waste

TABLE XII-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 324, 325, 326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Cement	Dry kiln	Fabric filter	35	1,260	99.5	1,250	30	380
		Multi-cyclone & old elect. precipitator	30	1,080	95	1,020	30	310
		Old elect. precipitator	10	360	90	320	30	100
		Multi-cyclone	5	180	80	140	0	0
		Wet scrubber	20	(720)[a]	95	(680) to SS water treatment		
		Total	100	3,600)	95	(3,410)	43	(1,470)
	Dry grinder	Fabric filter	35	490	99.5	490	30	150
		Multi-cyclone & old elect. precipitator	30	420	95	400	30	120
		Old elect. precipitator	10	140	90	130	30	40
		Multi-cyclone	5	70	80	60	0	0
		Wet scrubber	20	(280)	95	(260) to SS water treatment		
		Total	100	(1,400)	95	(1,340)	43	(570)
	Wet kiln	Fabric filter	20	820	99.5	810	30	240
		Precipitator	15	610	95	580	30	170
		Multi-cyclone	5	200	80	160	0	0
		Wetscrubber	60	(2,450)	95	(2,330) to SS water treatment		
		Total	100	(4,080)	95	(3,880)	71	(2,740)

TABLE XII-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates:								
Cement	Wet grinder	Fabric filter	20	130	99.5	130	30	40
		Multi-cyclone precipitator	15	100	95	90	30	30
		Multi-cyclone	5	30	80	30	0	0
		Wet scrubber	60	(390)	95	(370)	to SS water treatment	
		Total	100	(650)	95	(620)	71	(440)
Clay	All	None	22	0	n.a.	n.a.	n.a.	0
		Cyclone alone	35	420	75	310	0	
		Multi-cyclone	43	510	75	390	0	0
		plus scrubbers		(130)	60	(80)	to SS water treatment	
		Total		(1,060)	73	(780)	10	(80)
Total Residues from Air Pollution Control				6,820		6,310		1,580
WATER POLLUTANTS								
Suspended solids:								
Cement	Scrubber effluent	Lagoons	70	2,550	80	2,040	100	2,040
		Reuse	30	1,100	99	1,080	0	0
	Leaching	Lagoons	95	10	80	9	100	9
		Carbonation & adv. sedimen.	5	1	99	1	100	1
Clay	Scrubber effluent	Settling basins	100	80	85	70	100	70
Total				3,740	86	3,200	66	2,120

TABLE XII-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 324,325,326

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
TDS:								
Cement	Leaching	Lagoons	95	90	80	70	90	60
		Carbonation & adv. sedimen.	5	5	99	5	90	5
	Non-leaching	Coagulation & lagoons	70	10	80	8	90	7
		Reuse	30	5	99	5	0	0
Alkalinity:								
Cement	All	Neutralization	85	n.a.	n.a.	n.a.	0	0
		Carbonation	15	5	98	5	100	5
Total Residues from Water Pollution Control				3,850	86	3,290	67	2,200
Total Residues from Air and Water Pollution Control				10,670	90	9,600	39	3,780

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[a] Residues created during scrubbing are transferred to water as suspended solids, where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid wastes systems in the water pollutant estimates, since no solid wastes are created until water treatment occurs following intermedial transfer.

TABLE XII-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 324, 325, 326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Cement	Dry kiln	Fabric filter	35	1,410	99.5	1,400	25	350
		Multi-cyclone & old elect. precipitator	20	810	95	770	25	190
		Old elect. precipitator	10	400	90	360	25	90
		Multi-cyclone	15	600	99	600	25	150
		Wet scrubber	20	(810)[a]	95	(770)	to SS water treatment	
		Total	100	(4,030)	97	(3,900)	40	(1,550)
	Dry grinder	Fabric filter	35	550	99.5	550	25	140
		Multi-cyclone & old elect. precipitator	20	310	95	300	25	80
		Old elect. precipitator	10	160	90	140	25	40
		Multi-cyclone	15	240	99	230	25	60
		Wet scrubber	20	(310)	95	(300)	to SS water treatment	
		Total	100	(1,570)	97	(1,520)	40	(620)
	Wet kiln	Fabric filter	30	1,370	99.5	1,360	25	340
		Precipitator	25	1,140	95	1,080	25	270
		Multi-cyclone	5	230	80	180	0	0
		Wet scrubber	40	(1,820)	95	(1,730)	to SS water treatment	
		Total	100	(4,560)	96	(4,370)	54	(2,340)

TABLE XII-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates:	Wet grinder	Fabric filter	30	220	99.5	220	25	60
Cement (Cont.)		Multi-cyclone precipitator	25	180	95	180	25	40
		Multi-cyclone	5	40	80	30	0	0
		Wet scrubber	40	(290)	95	(280)	to SS water treatment	
		Total	100	(730)	96	(710)	54	(380)
Clay	All	None	10	n.a.	n.a.	n.a.	0	0
		Cyclone alone	40	530	75	400	0	0
		Multi-cyclone	50	670	75	500	0	0
		plus-scrubber		(170)	60	(100)	to SS water treatment	
		Total	100			(100)		(100)
Total Residues from Air Pollution Control				8,860	74	8,300	22	1,810
WATER POLLUTANTS								
Suspended solids:								
Cement	Scrubber effluent	Lagoons	60	1,850	80	1,480	100	1,470
		Reuse	40	1,230	99	1,220	0	0
	Leaching	Lagoons	60	9	80	7	100	7
		Carbonation & adv. sedimen.	40	6	99	6	100	6
Clay	Scrubber effluent	Settling basins	100	100	85	80	100	80
Total				3,190	87	2,780	56	1,560

TABLE XII-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 324,325,326

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
TDS:								
Cement	Leaching	Lagoons	70	70	80	60	75	40
		Carbonation & adv. sedimen.	30	30	99	30	75	20
	Non-leaching	Coagulation & lagoons	60	10	80	8	75	6
		Reuse	40	7	99	7	0	0
Alkalinity:	All	Neutralization	70	n.a.	n.a.	n.a.	0	0
Cement		Carbonation	30	10	98	10	100	10
Total Residues from Water Pollution Control				3,320	87	2,900	57	1,640
Total Residues from Air and Water Pollution Control				12,180	92	11,200	31	3,450

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[a] See footnote (a), Table XXI-8

TABLE XII-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Cement	Dry kiln	Fabric filter	40	1,830	99.5	1,820	25	460
		Multi-cyclone & old elect. precipitator	15	680	95	650	25	160
		Old elect. precipitator	5	230	90	210	25	50
		Multi-cyclone	25	1,140	99	1,130	25	280
		Wet scrubber	15	(680)[a]	95	(650)	to SS water treatment	
		Total	100	(4,560)	98	(4,460)	36	(1,600)
	Dry grinder	Fabric filter	40	720	99.5	710	25	180
		Multi-cyclone & old elect. precipitator	15	270	95	260	25	60
		Old elect. precipitator	5	90	90	80	25	20
		Multi-cyclone	25	450	99	440	25	110
		Wet scrubber	15	(270)	95	(260)	to SS water treatment	
		Total	100	(1,800)	97	(1,750)	36	(630)
	Wet kiln	Fabric filter	40	2,100	99.5	2,090	25	520
		Precipitator	30	1,570	95	1,490	25	370
		Multi-cyclone	5	260	80	210	0	0
		Wet scrubber	25	(1,310)	95	(1,250)	to SS water treatment	
		Total	100	(5,240)	96	(5,040)	42	(2,140)

TABLE XII-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Particulates:								
Cement (Cont.)	Wet grinder	Fabric filter	40	340	99.5	330	25	80
		Multi-cyclone & precipitator	30	250	95	240	25	60
		Multi-cyclone	5	40	80	30	0	0
		Wet scrubber	25	(210)	95	(200)	to SS water treatment	
		Total	100	(840)	96	(800)	42	(340)
Clay	All	Cyclone alone	45	690	75	520	0	0
		Multi-cyclone	55	840	75	630	0	0
		plus-scrubber		(210)	60	(130)	to SS water treatment	
		Total	100	(1,740)	74	(1,280)	10	130
Total Residues from Air Pollution Control				11,500	94	10,840	22	2,350
WATER POLLUTANTS								
Suspended solids:								
Cement	Scrubber effluent	Lagoons	30	700	80	560	100	560
		Reuse	70	1,640	99	1,620	0	0
	Leaching	Lagoons	20	3	80	2	100	2
		Carbonation & adv. sedimen.	80	10	99	10	100	10
Clay	Scrubber effluent	Settling basins	100	130	85	110	100	110
Total				2,480		2,300		680

TABLE XII-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
TDS:								
Cement	Leaching	Lagoons	40	50	80	40	60	20
		Carbonation & adv. sedimen.	60	70	99	70	60	40
	Non-leaching	Coagulation & lagoons	20	4	80	3	60	2
		Reuse	80	15	99	15	0	0
Alkalinity:								
Cement	All	Neutralization	30	n.a.	n.a.	n.a.	0	0
		Carbonation	70	30	98	30	100	30
Total Residues from Water Pollution Control				2,650		2,460		770
Total Residues from Air and Water Pollution Control				14,150	94	13,300	23	3,120

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[a] See footnote (a), Table XII-8

TABLE XII-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Cement	Dry kiln	Fabric filter	45	2,400	99.5	2,390	20	480
		Multi-cyclone	5	270	95	250	20	50
		Old elect. precipitator	5	270	90	240	20	50
		Multi-cyclone	30	1,600	99	1,580	20	320
		Wet scrubber	15	(800)[a]	95	(760)	to SS water treatment	
		Total	100	(5,340)		(5,220)		(1,660)
	Dry grinder	Fabric filter	45	930	99.5	930	20	190
		Multi-cyclone & old elect. precipitator	5	100	95	100	20	20
		Old elect. precipitator	5	100	90	90	20	20
		Multi-cyclone	30	620	99	620	20	120
		Wet scrubber	15	(310)	95	(300)	to SS water treatment	
		Total	100	(2,060)	98	(2,040)	32	(650)
	Wet kiln	Fabric filter	45	(2,740)	99.5	2,720	20	540
		Precipitator	35	2,130	95	2,020	20	400
		Multi-cyclone	5	300	80	240	0	0
		Wet scrubber	15	(910)	95	(870)	to SS water treatment	
		Total	100	(6,070)	96	(5,850)	31	(1,810)

TABLE XII-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
Particulates:	Wet grinder	Fabric filter	45	440	99.5	440	20	90
Cement (Cont.)		Multi-cyclone & precipitator	35	340	95	320	20	60
		Multi-cyclone	5	50	80	40	0	0
		Wet scrubber	15	(150)	95	(140)	to SS water treatment	
		Total	100	(980)	96	(940)	31	(290)
Clay	All	Cyclone alone	40	700	75	530	0	0
		Multi-cyclone -plus-scrubber	60	1,050 (260)	75 60	790 (160)	0 to SS water treatment	0
		Total		(2,010)	74	(1,480)	11	(160)
Total Residues from Air Pollution Control				14,030	95	13,300	18	2,340
WATER POLLUTANTS								
Suspended solids:								
Cement	Scrubber effluent	Lagoons	5	100	80	80	100	80
		Reuse	95	1,970	99	1,950	0	0
	Leaching	Lagoons	5	1	80	1	100	1
		Carbonation & adv. sedimen.	95	20	99	20	100	20
Clay	Scrubber effluent	Settling basins	100	160	85	140	100	130
Total				2,240	97	2,170	11	230

TABLE XII-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 324,325,326

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
TDS:								
Cement	Leaching	Lagoons	5	7	80	6	20	1
		Carbonation & adv. sedimen.	95	130	99	130	20	25
	Non-leaching	Coagulation & lagoons	5	1	80	1	20	0
		Reuse	95	20	99	20	0	0
Alkalinity:								
Cement	All	Neutralization	10	4	0	0	0	0
		Carbonation	90	40	98	40	100	40
Total Residues from Water Pollution Control				2,440	97	2,370	13	300
Total Residues from Air and Water Pollution Control				16,480	95	15,670	17	2,640

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[a] See footnote (a) to Table XII-8.

discharge twice, it is necessary to reduce the residues resulting from wet scrubbing by 33 percent. This calculation was made to determine the values for total residues before reuse for the suspended solids resulting from wet scrubbing.

It was also necessary to eliminate the separate reporting of residues resulting from potassium and sulfate removal to avoid double counting. These residues are included in the reporting of total dissolved solids. Potassium sulfate is presently worth $37 per kkg. It is estimated that ten percent of discharged potassium sulfate was recovered for sale in 1971. It is expected that by 1985 the price of potassium sulfate will be high enough to make recovery of 80 percent of the discharged potassium sulfate profitable.

Alkalinity is often handled by neutralization with acid. The Environmental Protection Agency recommends bubbling the stack gases through the wastewater to provide carbon dioxide acidity through a re-combination of calcium and other cations with the carbonate ion to form carbonate salts.[260] Calcium carbonate has a very low solubility and will precipitate out, resulting in a solid waste residue. The ratio of weight of calcium hydroxide to calcium carbonate is 1 to 1.3. Thus, the untreated discharge factor for alkalinity was multiplied by 1.3 prior to estimated total residue. Residues from cement manufacture are forecast to slightly increase from 1971 (3,697 x 10^6 kg) to 1985 (2,511 x 10^6 kg), while residues from clay manufacture are forecast to increase from 66 to 10^6 kg to 134 x 10^6 kg during the same period. These residue estimates may be given a confidence level of 2, indicating a possible 50 percent variation.

Composition of Solid Waste Residues from Pollution Treatment Processes.

The solid waste residues resulting from pollution treatments in cement and clay manufacture are nearly identical in composition to process materials. Thus, the residues can be fed back into the process materials if water and heat have not caused an irreversible reaction, such as solidification or caking of cement or clay. In general, the solid residuals are either dry particulates (lime, silica, alumina, iron oxide, and clay), or else the muds the particulates formed after capture by wet pollution control systems and consequent settling. Composition estimates are listed in Tables XII-12 (cement) and XII-13 (clay). The density-related data in these tables have been calculated from density figures given in Handy Engineering Data.[156] However, for clay, the porosity factor used was assumed to be 50 percent, similar to that of flour; this is a more realistic value than the 26 percent given, which probably pertains to puddled clay. The specific gravity of clay is 2.6. The figures given in Tables XII-12 and 13 are for dry residues. Figures for residues wetted to any saturation percentage can be easily derived on the assumption that the volume does not change with water content.

TABLE XII-12

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 324, 325

Item: Cement

Process or Activity:

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	1.0	156
Volume	l -wet	0.62	
H_2O content (of wet weight)	%	0.0	
Combustible	kg	0.0	
Non-combustible	kg	1.0	
Ash content	kg	1.0	
Liquid form	kg	0.0	
Solid form	kg	1.0	
Energy content	kcal	0.0	
Oxygen requirements	kg BOD_5	0.0	
Valuable metals	kg	0.0	
Volatile	kg	0.0	
Radioactivity	curies	0.0	
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg	0.0	
Non-biodegradable	kg	1.0	

TABLE XII-13

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 326

Item: Clay

Process or Activity:

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	1.0	156
Volume	l -wet	0.7	
H_2O content (of wet weight)	%	0.0	
Combustible	kg	0.0	
Non-combustible	kg	1.0	
Ash content	kg	1.0	
Liquid form	kg	0.0	
Solid form	kg	1.0	
Energy content	kcal	0.0	
Oxygen requirements	kg BOD_5	0.0	
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg		
Non-biodegradable	kg		

Factors Affecting Quality of the Data.

The cement manufacturing industry is presently in a state of flux after having remained stable for many years. Recent particulate emission limitations have necessitated the development of new control technology in the industry. Individual plants have responded to this stimulus by choosing various treatment methods. The practice of leaching kiln dust to lower the high-alkali content of dust was initiated as a response to air pollution control requirements. This dust was expensive to remove from the stack gas, and frequently disposal was expensive. The removal of alkali at a slight additional cost makes the collected dust suitable for recycling and results in overall savings. Subsequent water pollution effluent controls resulted in similar approaches. Cement manufacturing plants use a diversity of water pollution control methods.

Geography plays an important role. Various plants, for example, may have developed their particular methodology based on the proximity of an empty quarry which could be used for dust disposal. As a result of this diversity within the industry, recent data are quite erratic. For the same reasons, it is difficult to estimate the final course of the industry in response to the challenge of meeting point source limitations. There is almost no information for the clay products industry concerning treatment processes, the reuse of waste, or the disposal of treated solid and liquid wastes. Assumptions were made based on the data available. Treatment by cyclone processes was chosen because of its simplicity in design and relatively trouble-free operation. The combination cyclone-scrubber has a better removal percentage and it is assumed that it will be increasingly used in the future, increasing from 43 percent in 1971 to 60 percent in 1985.

As the dust collected in cyclones is composed only of clay particles, it is assumed that 100 percent will be reused. The combination of cyclone and wet scrubber is a good combination because 75 percent of the dust (100 percent in cyclone) can be reused, while only 15 percent goes into waste, thus creating less pollution for the same efficiency than if scrubbers alone are used.

The pollution caused by burned gas in the heating and firing steps are hard to estimate, and can vary over a wide range depending on the fuel used. If low sulfur fuel is used, the emission may be within permissible limits. The variation in fluoride emission can be large, depending on the composition of the clay used. The estimated fluoride emissions, based on the average fluoride of all clays, is assumed to be 0.55 kg per 1,000 kg of clay.[3] Fluoride emission can be brought to a low level by water scrubbing the kiln gases. It can be over 95 percent controlled with a single cyclone scrubber.[3] It is possible to control emissions of particulates or gases within the permissible limits using more efficient methods if there is justification for the higher cost. It is up to the industry to choose the method which best fits its needs and location. Location is important due to the quality of clay available, fuel used, and cost and availability of energy.

The overall confidence level of the data for cement and clay manufacture, given the above-listed factors, can be assigned a confidence level of 2, indicating a possible 50 percent variation in the data.

Summary.

Untreated discharges. The main pollutant generated during cement and clay manufacture is particulates. These are generated in large quantities (3.8 percent of the National uncontrolled particulate load) in the kiln feeding, grinding, and drying steps of cement manufacture, and in lesser quantities during the grinding, screening, blending, and storage steps of clay manufacture. Leaching of kiln dust in cement manufacture causes a transfer of particulates to water during cement manufacture. Total untreated discharges from cement and clay manufacture were forecast to almost double from 1971 (8,200 million kg) to 1985 (15,813 million kg).

Treatment methods. The large percentage of kiln dust and wastewater reused in both cement and clay manufacture lessens the potential impact on solid waste residues from pollution treatment processes. In the cement industry, solid waste residues will be created from kiln feeding in a slurry form and from wet grinding; both of these treatments control particulate emissions to the air. In clay manufacture, residues will be generated from settling ponds following cyclones and scrubbing treatments, again designed to control particulate emissions to the air.

Residues Generated from Pollution Control: Amounts and Types. Total residues from both cement and clay manufacturing pollution control were forecast to be 3,780 million kg in 1971, fall to 3,450 million kg in 1975, and continue falling to 3,120 in 1980 and 2,640 million kg in 1985. The majority of the residues will be from air pollution control rather than water pollution control, and the vast majority will be generated from cement manufacture (2,500 million kg in 1985) rather than clay manufacture (140 million kg in the same year). Although solid waste residues were forecast to decline, untreated discharges were forecast to monotonically increase through 1985; the divergence in patterns over time can be attributed mostly to the forecast increased amounts of reuse practiced by these industrial sectors. The residues generated from pollution control will mostly be particulates captured by the previously-described treatment processes, with some suspended solids where transfer to water occurs. The nature of the particulate residues will largely be lime, silica, alumina, iron oxide, and clay.

SECTION XIII
THE BLAST FURNACE AND BASIC STEEL INDUSTRIES
SIC 331

Introduction.

The Iron and Steel Industry (SIC 331 and 332) is a complex and important factor in the total environmental condition in the United States. Before controls, these two sectors are responsible for 12.7 percent of uncontrolled particulate emissions, 3.5 percent of the hydrocarbons, 2.7 percent of the carbon monoxide, and 7.9 percent of total suspended solids. The industry also contributes lesser amounts of other major pollutants. In the United States, the primary metal industries (including nonferrous metallurgy) accounted for approximately 20 percent of all energy used by industry in 1969 and 6.9 percent of the entire energy consumption.[114] This Section will evaluate only the blast furnace and basic steel industry (Sector 331), while Iron and Steel Foundries (SIC 332) will be evaluated in the following Section. The results stated in this Section have been given a confidence level of 2, indicating a possible 50 percent variation. This confidence level is a reflection of the accuracy of the available data.

Untreated Discharge Factors.

Air Pollutants. According to the Economics of Clean Air, 2,091 thousand metric tons of particulates were emitted from iron and steel mills in 1968 when the industry control level was 55 percent.[36] The untreated discharges are then calculated to be 3,800 thousand metric tons. Projections to 1977 indicate a reduction to 3,284 thousand metric tons, assuming a continuation of the 55 percent control level. The estimates in this source, however, include only sintering and furnace operations. The Intermedia Aspects of Air and Water Pollution Control[11] estimated present uncontrolled particulate emissions at 9,829 thousand metric tons and included all steel plant operations, with the exception of sintering, which was included in metal mining.

Fluorides were mentioned as a possible pollutant in the 1971 Economics of Clean Air,[3] but were not included in the 1972 edition.[36] The only reference to fluorides in the 1972 edition is the statement they are not yet subject to specific emission standards. Since the 1971 edition indicates there were only 23.6 thousand metric tons of fluoride emissions in 1967, their exclusion will not have a significant effect on the estimated total weight of solid residue.

Coking yields several gaseous pollutants which may yield solid residues, such as sulfur oxides, ammonia, benzene, and toluene. Of these, ammonia is the only pollutant of significant weight.

Table XIII-1 shows estimated untreated discharge factors for air pollutant emissions by process. It is clear that the alternate estimates shown vary widely with the lowest estimates yielding 4.6 billion kilograms total uncontrolled particulate emissions, and the highest, 10.8 billion kilograms at 1970 steel production levels. It is felt that these

TABLE XIII-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 331

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Coking	Beehive	Tons coal	Particulates	100	10
	By-product			1	10
		Tons coke	Ammonia	3.44	
Reduction	Blast furnaces	Tons iron	Particulates	65	10
				20	119
				15	90
Steel furnaces	Open hearth	Tons steel	Particulates	8.5	10
				10	90
	Basic oxygen	Tons steel	Particulates	20	10
				25-30	90
	Electric arc	Tons steel	Particulates	5	10
				12.5-15	90
Scarfing		Tons steel produced	Particulates	1.5	10
		Tons steel scarfed		14.5	121
Materials handling		Tons steel	Particulates	5	10
Sintering		Tons sinter	Particulates	21	10

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[a] For 1971 or most recent available information.

variations indicate a substantial degree of uncertainty in the data. The estimated discharge factors are, therefore, given a confidence level of 3, indicating a possible variance of 25 percent in the data.

Water Pollutants. The water pollutants generated in steel mills include suspended solids, oils, and various chemicals.[91] The oils appear in the form of lubricants from machining and forging, fuel oil from furnaces and soaking pits, solvents from painting and degreasing operations, and tars and pitch from coke ovens. These are collected and disposed of to landfills, or incinerated. Suspended solids in the form of fly ash from coal-fired furnaces are used to cement material. Scale from sinter plants and blast furnaces are recovered from the air washers along with scale from rolling mills. Suspended solids from open hearth and basic oxygen furnaces may also be recovered as sinter if they are low in zinc; otherwise they are discharged to the slag pile. Pickle liquor, which constitutues a large portion of the chemical effluent, may either be regenerated or neutralized by lime.

Table XIII-2 lists water pollutants produced per ingot-ton of product for the various manufacturing steps in a typical plant. It is clear from the table that the overwhelming proportion of water pollutants is composed of suspended solids and iron sulfate. Suspended solids originate mainly in blast furnaces, sintering, and rolling mills. Iron sulfate and sulfuric acid are by-products of the pickling process.[151] Included in the water pollutant figures are dusts scrubbed from the stacks of blast furnaces and steel furnaces. This exchange must be taken into account when solid waste residues from air and water pollution control are calculated at the conclusion of this discussion. Table XIII-3 lists a more complete analysis of wastewater from still mills. A confidence level of 2 (indicating a ±50 percent variation in the data) can be given to available untreated discharge factors.

TABLE XIII-2

SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE[151]

SIC 331

Item	Process or Activity	Pollutant	Kg Pollutant (Dry) per Ingot Ton
Coking		Ammonia	0.048
		Cyanide	0.007
		Phenol	0.037
Reduction	Blast furnace	Suspended solids	33.3
		Ammonia	0.011
		Cyanide	0.014
		Phenol	0.014
		Fluorides	0.023
Steel furnaces	Open hearth and basic oxygen	Suspended solids	42.0
Sintering		Suspended solids	11.2
Rolling mills		Suspended solids	42.0
Pickling		Free acid	2.25
		Combined acid	8.4

TABLE XIII-3

WATER POLLUTANTS FROM BLAST FURNACES AND BASIC STEEL PRODUCTION[151]

	Kg per Ingot Ton			
	Old Plants	Typical Plants	Advanced Plants	Total
% of Total Production	33.3	55.4	11.3	100.0
Waste				
Suspended solids	51.5	62.5	92.0	62.17
Phenols	0.0345	0.032	0.032	0.033
Cyanides	0.0145	0.014	0.0155	0.0145
Fluorides	0.0165	0.0155	0.0159	0.016
Ammonia	0.0410	0.039	0.039	0.0395
Lube Oils	1.54	1.36	1.185	1.400
H_2SO_4	1.515	1.77	1.415	1.695
$FeSO_4$	5.65	6.6	5.25	6.131
Emulsions	0.166	0.207	0.585	0.066
Chromium	-	0.0315	0.0315	0.0215
Zinc	-	-	0.00125	0.00015
Tin	-	0.008	0.008	0.0055
$FeCl_2$	-	-	1.05	0.1185
HCl	-	-	0.2825	0.032
Totals	60.5	72.6	101.9	71.7
Liters H_2O/metric ton	33,859	34,341	47,218	35,636

Industry Description and Schematic.

Sector 331 of the SIC includes blast furnaces, steel works, and rolling and finishing mills. The important production steps in this sector are shown in Figure XIII-1. Blast furnaces use iron ore from mines and coke from coking plants. Coke is produced by driving off the volatile matter in coal, yielding coke as a solid residue. Coke is then used for reducing ore in the blast furnace. An alternative process is the direct reduction of iron ore with the aid of reducing fuels, mostly natural gas.[123]

Iron ore is first sent to a sinter plant, or if the ore particles are very fine, to a pelletizing plant. The sinter or the pellets are then sent to a blast furnace, sometimes with scrap, where they are reduced and melted. The molten material is cooled to form pig iron, the basis for the production of most raw steel. Limestone is also added to the blast furnace, and its calcium content combines with impurities in the ore and coke (silica, alumina, phosphorus, sulfur and other metallic oxides) to form slag,[117] a material commonly used for building materials, concrete aggregates or insulating material.[91] When iron ore is reduced by direct reduction processes, iron pellets or briquettes are usually fed to the electric arc furnace, with which the direct reduction process is usually associated.

The production of raw steel is accomplished in an open-hearth furnace, a basic oxygen furnace, or an electric arc furnace. In these furnaces, the carbon content of the iron is reduced to make molten steel, which is tapped from the furnace and shaped by the continuous casting process or formed and rolled by conventional processes. Subsequent finishing operations involve scaling, scarfing and/or pickling, wherein the scale and other materials are removed from the surface of the steel.

Economic Forecasts.

The two main economic factors which will influence future pollution treatment requirements and discharge factors for the steel industry in the United States are the industry's growth (which is closely related to American economic conditions) and changes in steel making technology. These two factors are discussed below.

Growth factors. The demand for steel is a derived demand, and as such, the growth of the steel industry is stimulated by the pattern of demand in major consuming industries - construction, automotive, heavy machinery, and appliances. Projected growth in these traditional steel-using sectors, as well as new or emerging demands, is expected to generate a continuing increase in the consumption of finished steel in the United States. Some of the factors which are expected to contribute to growth in demand for steel are:

1. The need to utilize large tonnages of structurals and plates for modernizing or replacing the obsolete and inadequate infrastructure of the U.S. economy.

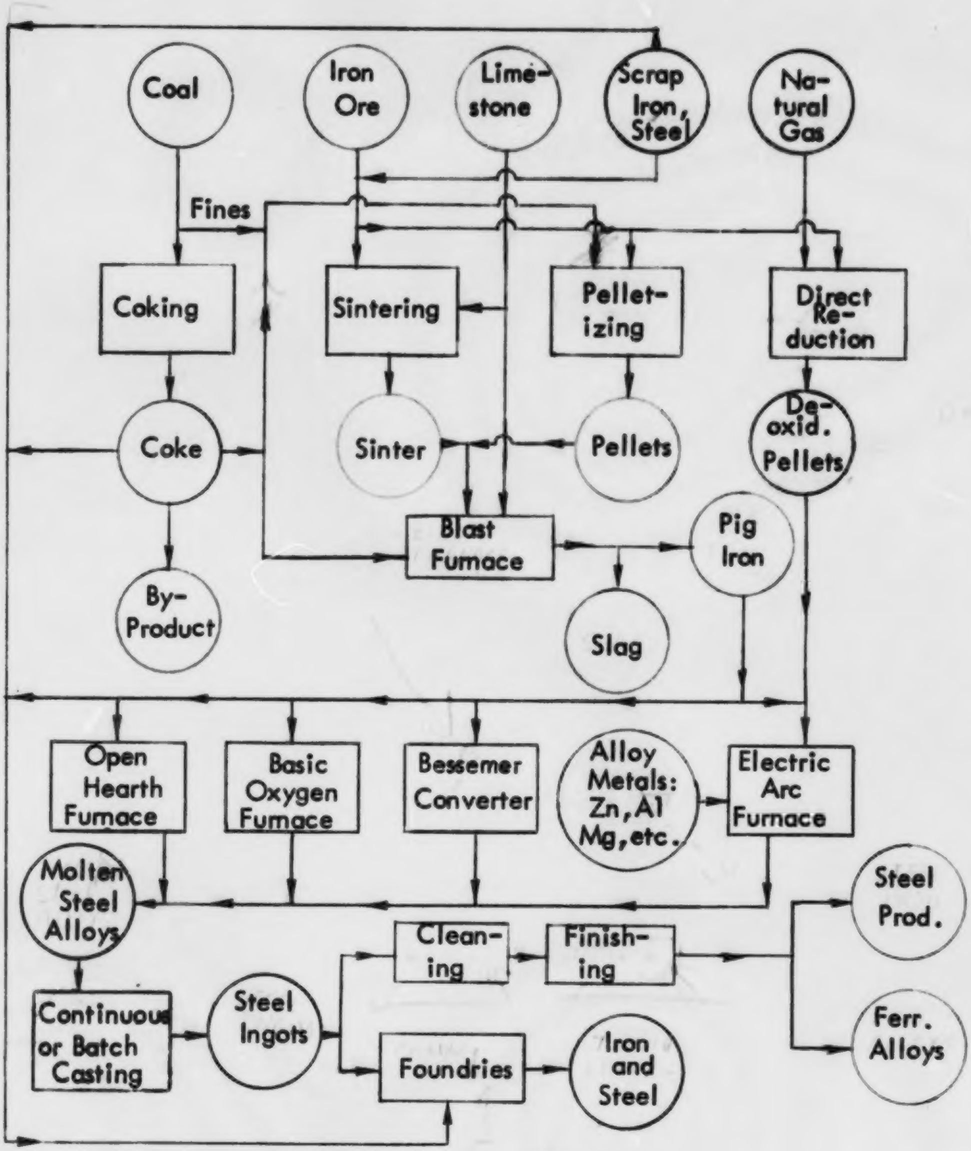
Coal
Iron Ore
Lime-stone
Scrap Iron, Steel
Na-tural Gas
Fines
Coking
Sintering
Pellet-izing
Direct Re-duction
Coke
Sinter
Pellets
De-oxid. Pellets
Blast Furnace
Pig Iron
By-Product
Slag
Open Hearth Furnace
Basic Oxygen Furnace
Bessemer Converter
Alloy Metals: Zn, Al Mg, etc.
Electric Arc Furnace
Molten Steel Alloys
Steel Prod.
Clean-ing
Finish-ing
Continuous or Batch Casting
Steel Ingots
Foundries
Iron and Steel
Ferr. Alloys

FIGURE XIII-1
INDUSTRY SCHEMATIC:
IRON AND STEEL INDUSTRY
PRODUCTION PROCESS OVERVIEW

2. Steady growth in demand for durable consumer goods, such as automobiles, appliances, and housing, particularly factory-built and mobile homes, can be expected from gains in per capita disposable income and population growth.

3. A new steel market derived from the need to construct the plant and equipment, as well as the huge ocean vessels, required to carry out the large scale importation of liquefied natural gas and petroleum supplies which may be necessary to meet the expanding energy needs of the United States in coming years.

Technological Trends. In the last ten to fifteen years, the Iron and Steel Industry in the United States and other major producing nations made tremendous progress in its technology. This has permitted a saving in raw materials, increased efficiency of equipment, an improved quality of products, and a higher degree of pollution control. The most notable successes have been achieved in three major areas:

1. The development of direct reduction processes as an alternative to the blast furnaces in the process of iron-making.

2. The elimination of the Bessemer Converter and the decline of the open-hearth furnace, to be replaced by the basic oxygen furnace (BOF) and the electric furnace.

3. The advent of continuous processes for casting, rolling and finishing of steel as a viable alternative to the conventional ingot casting and rolling processes.

Direct reduction of iron ore produces iron briquettes or pellets containing more than 90 percent iron which can be used in electric furnace steel-making to replace or supplement scrap. Direct reduction thus provides a means of eliminating the blast furnace and associated coke ovens, and has found its most economical use in combination with the electric furnace. This combination becomes advantageous where:

1. Growth in electric furnace capacity is high.
2. Available supplies of scrap iron are limited or expensive.
3. Natural gas and other reducing fuels are in abundant supply, or the supply of coking coal is limited.
4. The costs of constructing the blast-furnace and related coke ovens is found prohibitive.

Currently, direct reduction processes are projected to produce 5 million metric tons of iron in 1980. This would be a tremendous increase over the current output of 2 million metric tons, but would still be a very minor share of total United States production. On the probable assumptions that supplies of coking coal and iron ore to the United States steel industry continue to be abundant, while the supply of low-cost domestic natural gas diminishes, it appears unlikely that any sweeping replacement of the blast furnace by direct reduction will occur in the near future. The direct reduction process may be more widely adopted in the future, however, where expansion of iron making capacity at relatively lower capital costs is required.

The most important innovation in the steel-making sector in recent years has been the conversion from the conventional open-hearth furnace to the basic oxygen and the electric furnaces. The share of steel output produced by the open-hearth furnace has declined from 55.6 percent in 1967 to 27.6 percent in 1972, while the basic oxygen process has increased its share from 32.5 percent to 56.3 percent in the same period. The share of the electric furnace has grown slowly but steadily from 11.8 percent to 17.7 percent.

It is generally agreed that new steel making techniques such as basic oxygen furnaces will increasingly replace the open-hearth furnace in the next decade.[88] Currently, a major portion of open-hearth furnace capacity is considered to be obsolete and also to represent a severe air pollution problem since control equipment can be installed only at a prohibitive cost.[88] Of the estimated 53 million metric tons of current open-hearth capacity, it is projected that 23 million metric tons will be phased out by 1980, to be replaced by either basic oxygen or electric arc furnaces.[88]

The basic oxygen furnace (BOF) and its variant, the bottom-blown process (Q-BOP), is projected to continue to increase its share of United States steel-making capacity. Basic oxygen furnace capacity is predicted to expand to about 76 million metric tons in 1977,[132] and could reach 86 million metric tons by 1985.

Electric-furnace operations have grown dramatically in the post-war period, shifting from use in small "specialty steel" facilities to large mills producing predominantly carbon steel. Current capacity, which is estimated at 31 million metric tons,[84] is expected to expand in the next decade to become the second major producer of domestic steel as the industry replaces existing open hearth furnaces and increases overall capacity. Several factors, including adaptability to limited production at relatively lower capital and operating costs and pollution control capabilities, are expected to favor this method of steel-making as the industry pursues programs of massive capital investment in expanding facilities and implementing pollution control standards.[85] Electric furnace capacity is projected to reach about 77 million metric tons by 1985, an average annual gain of about 10 percent.[133]

The continuous casting process represents one of the major technological advances of the steel industry in the post-war period. The process bypasses several steps in steel refining by taking steel directly from the furnace into a continuous caster to produce a semi-finished steel in the form of a slab, billet or bloom, with a yield of 95 percent or more. This compares most favorably with the conventional process whereby ingots are formed and rolled on a mill at a yield of approximately 85 percent. This process, which was introduced commercially in the United States only ten years ago, has been widely adopted; current estimated capacity is about 15 million metric tons.[88] It is expected in the years ahead that new steel-making facilities will incorporate the continuous casting process almost exclusively.[88] If 90 percent of the projected 50 million metric tons of new steel-making capacity utilizes the continuous casting process, continuous casting capacity may be expected to increase to about 54 million metric tons by 1980. Available forecast data for blast furnaces and basic steel mills are summarized in Table XIII-4. These estimates have been reconciled with each other and are used in the forecasts of Table XIII-5.

Final Forecast. Table XIII-5 takes into account the above-described industry growth and technological trends to arrive at a final forecast. The statistics presented in Table XIII-5 represent a compilation of the statistics previously cited with interpolation to provide the missing data. Some basic assumptions were necessary and these are explained in the footnotes to the table. These assumptions create a certain possibility for error. Additional error is introduced as a result of the inability to predict the effect of foreign imports on the United States market. The amount of foreign imports is a function of tariffs, international agreements and world conditions, which are difficult to predict. Therefore, the results presented here are given a confidence level of 3, indicating 25 percent possible variation in the data. This final forecast will be used in the calculation of total residues from blast furnaces and basic steel mills which are compiled at the end of this chapter.

TABLE XIII-4
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 331

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Raw steel	Capacity	10^6 tons	1973	150			177		88	1972
	Production		1973	128		138	157	175	68	1973
					109				83	1973
Steel mill products	Consumption	10^6 tons	1973	99					83	1973
							119		130	1973
	Shipments		1973	86					83	1973
	Imports					17	19	22	68	1973
Reduction	Direct reduction	10^6 tons	1973	2					88	1972
Steel furnaces	Open hearth	10^6 tons			32				85	1971
	Basic oxygen				58					
			1973	58					127	1973
	Electric arc				19				85	1971
Casting	Continuous casting	% of new production	1972–1980	95%					88	1972
		10^6 tons capacity	1972	15						
Steel products	Consumption	% growth per year	1973–1980	2.5%					130	1973
	Exports	10^6 tons	1972 1973	2.9 3.2	2.8				83	1973

TABLE XIII-5

COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 331

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Raw steel	Capacity	10^6 tons	128	a	157	b	177	88	201	c
	Production		109	83	138	68	157	68	175	68
Steel products	Consumption	10^6 tons	93	83	104	d	119	130	134	e
	Shipments		79	83	95	68	107	68	121	68
	Imports		17	83	17	83	19	130	22	e
Coking	All	10^6 tons coke	59	f	55	f	67	f	67	f
Steel furnaces	Open hearth	10^6 tons steel	32	85	20	g	15	g	12	g
	Basic oxygen		58		75		78		89	
	Electric arc		19		43		64		75	
Scarfing		10^6 tons steel	109	h	138	h	157	h	175	h
Material handling		10^6 tons steel	109	h	138	h	157	h	175	h
Sintering		10^6 tons iron	42	i	38	i	32	i	28	i
Rolling mills		10^6 tons steel	109	h	138	h	157	h	175	h
Pickling		10^6 tons steel	54.5	j	69	j	78.5	j	87.5	j
Pig iron	Blast furnaces	10^6 tons steel	74	k	88	k	107	k	107	k

TABLE XIII-5 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 331

[a] Calculated from production of 109 million metric tons (Ref. 83) at 85 percent capacity.

[b] Independent forecast based on interpolation of 1971 to 1980 projected increase from a above and Ref. 88.

[c] Required capacity to meet forecast of 175 million metric ton output at 85 percent capacity.

[d] Interpolation of forecast 1973-1980 growth rate of 2.5 percent from Ref. 130.

[e] Extrapolation of 1980 data using 2.5 percent per year growth from Ref. 130.

[f] Calculated from trends in amount of coke required per ton of pig iron in Ref. 155.

[g] These figures are estimated from the known decline in the use of open-hearth furnaces and Ref. 85 forecast of 22 million metric tons of open-hearth capacity at 70 percent utilization. Electric arc furnaces have shown the fastest growth in recent years.

[h] Assumed equal to total new steel production.

[i] Estimated from increasing use of pelletizing and resultant decline in sintering.

[j] 50 percent of steel is pickled (Ref. 121).

[k] Estimated from percent of steel produced domestically from pig iron from blast furnace reduction of iron ore.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table XIII-6 is a compilation of total air and water pollutant discharges before treatment by the Steel Industry in the United States for the years indicated. The data it contains were obtained by multiplying the discharge factors given in Tables XIII-1 and XIII-2 by the forecasts for future production listed in Table XIII-5.

Likely Pollution Treatment Processes.

Efficiency levels and solid residue impacts of the various air and water pollution treatment methods are presented in Table XIII-7. Air and water pollution control processes are discussed separately below. The data from which Table XIII-7 was generated were basically treatment cost forecasts. These forecasts showed large variations, resulting in a confidence level of 1 for the cost data, indicating a possible 100 percent variation. Because of the difficulty in predicting which treatment processes would be used in the future, the treatment levels have been given a confidence level of 3, indicating a possible 25 percent variance.

Air Pollution Control. As shown in Table XIII-7, the potential efficiency levels for the blast furnaces and three types of steel furnaces are quite high. The blast furnaces may achieve a level of 99 percent, while the steel furnaces may achieve a control level of 97 to 99 percent. Treatment processes are illustrated in Figure XIII-2.

Only the coke plants have resisted attempts to control dust emissions. The beehive method of coking has remained completely uncontrolled, since the currently required control equipment cannot be adapted for installation on older coke ovens. Thus, it is not expected that emissions of particulates and other gases from coking will be significantly controlled before 1977.[89] Thereafter, investments in an improved coking process to replace many older coking plants will result in more effective control in the coking process.[89]

Particulates from the blast furnace are principally composed of iron oxides and carbon. They are collected directly by dry dust catchers, such as fabric filters or electrostatic precipitators, or by wet cleaning devices such as scrubbers.[117] Precipitators are usually flushed with water, converting the particulates to suspended solids. The residues from the dry processes are recycled to the sintering process. The suspended solids are concentrated and settled in a thickener and then dried, sintered and recycled.[91,121] Thus, for dry collectors at high efficiencies, 15 to 65 kg solid residues for recycling are created for each ton of pig iron produced. The solid residues from wet collectors depend on the water treatment techniques, to be discussed in the next section.

TABLE XIII-6
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 331

Pollutant: Item	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged 1971	1975	1980	1985
AIR POLLUTANTS:						
Particulates:						
Coking	Beehive	10	5,920	5,475	6,680	6,690
	By-product		59.2	54.75	66.8	66.9
Reduction	Blast furnace	10	4,810	5,694	6,948	6,955
Steel furnace	Open hearth	10,121[a]	296	185	139	111
	Basic oxygen		1,580	2,032	2,125	2,425
	Electric arc		166	376	560	656
			882			
Sintering		10		798	672	588
Materials handling		10	545	690	785	875
Scarfing		10	163	207	235	263
Total			14,431	15,497	18,217	18,622
Ammonia:						
Coking		11	203	189	230	230
WATER POLLUTANTS:						
Suspended Solids:						
Reduction	Blast furnace	151	2,464	2,917	3,560	3,563
Steel furnace	Open hearth and basic oxygen		3,780	3,990	3,906	4,242

TABLE XIII-6 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 331

Pollutant: Item	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Sintering		151	470	426	358	313
Rolling mill			4,578	5,796	6,594	7,350
Total		11,298	11,292	12,092	14,418	15,468
Ammonia:						
Coking		151	2.84	2.63	3.21	3.21
Cyanide:						
Coking		151	0.41	0.38	0.47	0.47
Phenol:						
Coking		151	2.19	2.02	2.47	2.48
$Fe SO_4$						
Pickling			458	580	659	735
$H_2 SO_4$						
Pickling			123	155	177	197

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[a] Average of two data sources.

TABLE XIII-7

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE SIC 331

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Coking	Beehive	Particulates	None				
	By product	Particulates	None				
	All	Ammonia	Sulfuric acid scrubbing	90	3.88		121
Reduction	Blast furnaces	Particulates	Filters and precipitators	99	1		10
			Scrubbers	99	1		
		Phenols	Benzol quenching	81	1		
		Cyanides	Benzol quenching	98	1		
		Ammonia	Benzol quenching	99	1		
Steel furnaces	Open hearth	Particulates	Precipitators	99	1		10
			High energy wet scrubbers	97			
	Basic oxygen		Precipitators	99	1		
			High energy wet scrubbers	99	1		
	Electric arc		Precipitators	99	1		
			Wet scrubbers	99	1		
			Fabric filters	99	1		
Sintering		Particulates	Med. energy wet scrubbers	90	1		10

TABLE XIII-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 331

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Sintering and blast furnaces		Suspended solids	Sedimentation	93.8	~ 1		151
			Coagulation and sedimentation	98.2	~ 1		
			Recirculation and sedimentation	98.8	~ 1		
			Recirc., sediment and coag.	99.6	~ 1		
Scarfing		Particulates	Dry treatments	90	1		10
			Wet treatments	90	1		
Material handling		Particulates	Dry treatments	90	1		10
			Wet treatments	90	1		
Rolling mills		Suspended solids	Sedimentation	90.7	~ 1		151
			Coagulation and sedimentation	95.4	~ 1		
			Recirc. and sedimentation	96.9	~ 1		
			Recirc., coag. and sedimentation	98.4	~ 1		

TABLE VIII-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
CAPABLE OF GENERATING SOLID WASTE
SIC 331

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Pickling	Pickle liquor	$Fe\ SO_4$	Lime neutral. with sedimentation	80	1.4		121
			Evaporation - crystallization	95	1.12		
			Crystal roasting	95	~ 1		
		$H_2\ SO_4$	Lime neutral. with sedimentation	80	1.57		
			Evaporation - crystallization	100	1		
			Dialysis	50-75	~1		

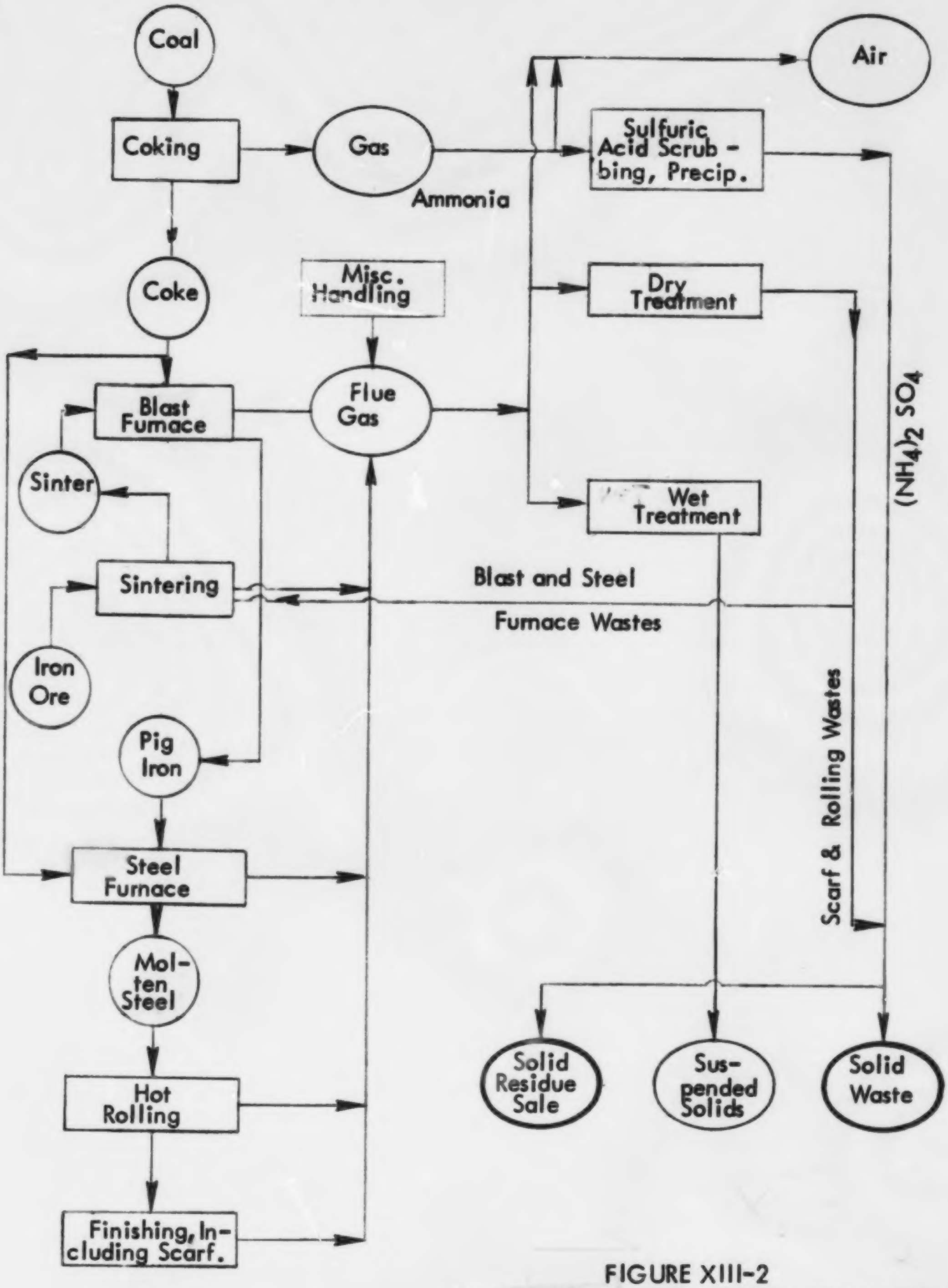
Coal
Coking
Gas
Ammonia
Air
Sulfuric Acid Scrubbing, Precip.
Coke
Misc. Handling
Dry Treatment
Blast Furnace
Flue Gas
Sinter
Wet Treatment
Sintering
Blast and Steel
Furnace Wastes
Iron Ore
Pig Iron
$(NH_4)_2SO_4$
Scarf & Rolling Wastes
Steel Furnace
Molten Steel
Hot Rolling
Finishing, Including Scarf.
Solid Residue Sale
Suspended Solids
Solid Waste

FIGURE XIII-2
AIR POLLUTION TREATMENT SCHEMATIC:
BLAST FURNACES AND BASIC STEEL PRODUCTION

Treatment in the steel furnaces is similar to treatment of blast furnace flue gases. Open-hearth furnaces produce large quantities of dust with finer particles than those from blast furnaces. Precipitation equipment, scrubbers, or both may be used in the control of the flue gases. If the zinc content is sufficiently low, the recovered dust may be used for sintering.[90] A high zinc content can be damaging to the refractory lining of the blast furnace.[90] If the solid residues are not recycled, 8.5-10 kg of solid waste per metric ton of steel are created.

Basic oxygen furnaces emit higher levels of particulates than open hearth furnaces. The gas cleaning equipment is similar to that used on the open-hearth, although there are variations in methods of washing and removing accumulated dust from the washers and precipitators. For the dust collected in solid form, 20-30 kilograms of solid residue per metric ton of steel are produced if the material is not recycled. Zinc content considerations are again important.

Electric arc furnaces can be used for the production of steel or ferroalloys. The charge is reduced by an electric current and the violent activity in the area of the electrodes causes a rather high discharge of dust. Fabric filters are usually used for electric arc furnaces. Depending upon the final method used for removal of the suspended solids from water and the destination of these residues, solid wastes may be generated. About 5-15 kilograms of suspended solids per metric ton of steel are generated annually.

There are several types of scarfing processes in use today. Upon completion of the scarfing, the semi-finished product is ready for subsequent rolling operations or, in some instances, may pass to an operation that removes surface defects. The emissions from the scarfing processes are not usually recycled and end up as solid wastes from water pollution control of the scrubbing water.

Sintering is generally controlled by washers or bag houses. The residues created are usually recharged to the sintering process. As pelletizing replaces the sintering process, particulate emissions and the residues generated by their control will both decline.

Miscellaneous air pollutants include fluorides, whose control is intramedial in that their control rests with the use of low fluoride ores, and ammonia. Ammonia may be stripped from the flue gases from coke ovens through contact with sulfuric acid.[119] This yields ammonium sulfate, as shown in Equation XIII-1:

$$\text{(XIII-1)} \qquad H_2SO_4 + 2\,NH_3 \longrightarrow (NH_4)_2\,SO_4$$

$$\text{molecular weights} \qquad 98.07 + 34.02 \qquad\qquad 132.09$$

For every kilogram of ammonia in the coke gas, 132.09/34.02 or 3.88 kilograms of ammonium sulfate are created through contact with 98.07/34.02 or 2.88 kilograms of sulfuric acid. According to Pollution Control Technology, 12 kilograms of saleable ammonium sulfate are produced per metric ton of coke.[121] Pollution Control Technology also estimates 1 kilogram per ton of phenol and 10 kilograms per ton of napthalene, benzene, xylene, and cresols per metric ton of coke.[121]

Water Pollution Control. Since most air pollutants are controlled by wet treatment processes, the handling of water pollutants is the main factor in determining the solid waste impact of pollution control in steel mills. Table XIII-8 estimates the major water treatment method application rates and efficiencies as they are applied to suspended solids. Treatment processes are illustrated in Figure XIII-3.

Currently, plain sedimentation accounts for 60 percent of all treatment of blast furnace and sinter plant effluents. This percentage is forecast to decrease to 40 percent by 1977 in favor of more coagulation and recirculation of the wastewaters. Since plain sedimentation is a simple physical removal method, the residues generated will equal the particulates scrubbed from the flue gases plus any primary water pollutants, which are minor in this case. The use of coagulants will not greatly increase this waste. According to one study, the use of various polymers as electrolytes(up to 5 ppm concentration in wastewaters) reduced suspended solids concentrations by 32.2 to 35.6 mg/l.[119] This is a ratio of 6.44 to 7.13 kilograms of additional suspended solids removal per kilogram of polyelectrolyte added. Since the original concentration was 345 mg/liter, which was reduced to 58 mg per liter by sedimentation alone, the total removed suspended solids amounted to 329.2 to 333.2 mg/l liter with a maximum of 5 ppm of polyelectrolyte added.[119] Thus, the weight of polyelectrolyte was only at most 1.5 percent of the weight of suspended solids removal. This weight would be incorporated into the solid residues from the water treatment processes. If the residues are recycled, most of the weight of the polyelectrolyte would go off as gaseous emissions. If no recycling was done, it would increase solid wastes by only a minor amount. Therefore, the weight of solid residues can be estimated by the weight of solid residues removed. The trend in hot rolling mills is also toward more advanced treatment. Coagulation is to play an increasing role at least through 1977. Again, the weight of the polyectrolyte is not a significant factor in the weight of solid residues.

The chemicals in waste pickling liquor are also of significance to the impact of water pollution controls in solid waste management. Although at the present time pickling is done mostly with sulfuric acid, major steel strip manufacturers are switching toward the use of hydrochloric acid.[121] The price of this acid is becoming lower, while that of sulfuric is becoming higher, and hydrochloric acid and pickle liquor can be regenerated.[121] The ferrous sulfate is currently separated as a solid residue.

Where sulfuric acid is used, neutralization with lime is sometimes practiced. Magnetic iron oxide is formed along with crystalline gypsum. These products may be recovered and reused, the gypsum being used for wall-board or cement manufacture. Where no recovery is practiced, the solids may be disposed of in landfills. Estimates give the discharge of ferrous sulfate at 8.4 kilograms per metric ton of iron, and the discharge of free acid at 2.25 kilograms per metric ton of waste acid.[151]

TABLE XIII-8

NET CONTROL CALCULATIONS FOR WATER POLLUTANTS IN BLAST FURNACES AND BASIC STEEL PRODUCTION[151]

Source and Treatment Process	1972			1977		
	Application %	Efficiency %	Net %	Application %	Efficiency %	Net %
Blast furnace and sinter plant						
Plain sedimentation	60	93.8	56	40	93.8	38
Coagulation and sedimentation	15	98.2	15	25	98.2	25
Recirc. and plain sedimentation	15	98.8	15	20	98.8	20
Recirc., coag., and sedimentation	10	99.6	10	15	99.6	15
Net efficiency total	100		96	100		98
Hot rolling mills						
Plain sedimentation	55	90.7	50	40	90.7	36
Coagulation and sedimentation	5	95.4	5	10	95.4	10
Recirc. and plain sedimentation	25	96.9	24	30	96.9	29
Recirc., coag., and sedimentation	16	98.4	15	20	98.4	20
Net efficiency total	100		94	100		95

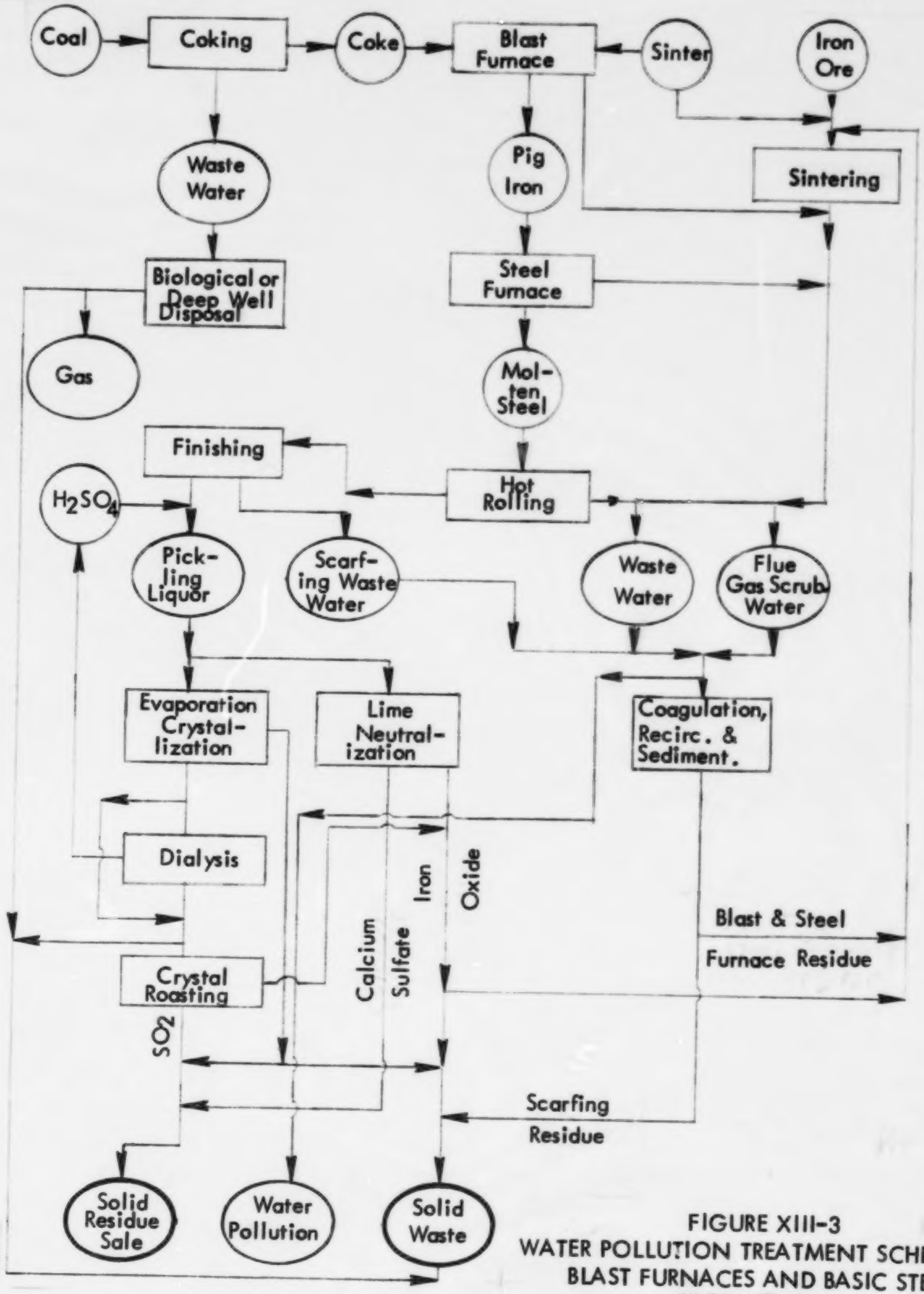
Coal
Coking
Coke
Blast Furnace
Sinter
Iron Ore
Waste Water
Pig Iron
Sintering
Biological or Deep Well Disposal
Steel Furnace
Gas
Molten Steel
Finishing
Hot Rolling
H2SO4
Pickling Liquor
Scarfing Waste Water
Waste Water
Flue Gas Scrub Water
Evaporation Crystallization
Lime Neutralization
Coagulation, Recirc. & Sediment.
Dialysis
Iron Oxide
Calcium Sulfate
Blast & Steel Furnace Residue
Crystal Roasting
SO2
Scarfing Residue
Solid Residue Sale
Water Pollution
Solid Waste

FIGURE XIII-3
WATER POLLUTION TREATMENT SCHEMATIC: BLAST FURNACES AND BASIC STEEL PRODUCTION

The reactions are listed below:

(XIII-2) $H_2SO_4 + CaO \longrightarrow CaSO_4 \quad H_2O$

molecular weights $98.07 + 56.08 \qquad 136.15 + 18$

(XIII-3) $1/2\ O_2 + 3\ CaO + 3\ Fe\ SO_4 + 3\ H_2O \longrightarrow 3\ CaSO_4 \quad H_2O + Fe_3\ O_4$

molecular weights $16 + 168.24 + 455.76 + 54 \qquad 462.45 + 231.59$

Thus, every kilogram of free sulfuric acid yields 154.15/98.07 or 1.57 kilograms of calcium sulfate monohydrate. Every kilogram of ferrous sulfate yields 462.45/455.76, or 1.01 kilograms of calcium sulfate monohydrate, and 231.55/455.76 or .408 kilograms of iron oxide. Thus, 8.4 kilograms of ferrous sulfate and 2.25 kilograms of free sulfuric acid would yield 3.43 kilograms of iron oxide and 21.72 kilograms of calcium sulfate (gypsum) in monohydrate form. Pollution Control Technology estimates 12.5 - 17.5 kilograms of iron oxide and 20 to 25 kilograms of gypsum solid residue per metric ton of iron yielding $0.22 to $0.44 per ton in resale value if the product is sold.[121]

Evaporation-crystallization has been used in producing ferrous sulfate crystals. The crystals are separated from the liquor by centrifugation, the free sulfuric acid remaining in solution.[121] Here the only solid residue is the original weight of ferrous sulfate in the solution in monohydrate form ($FeSO_4 \cdot H_2O$) which is 169.92/151.92 or 1.12 kilograms per kilogram of ferrous sulfate originally in solution.

Dialysis may be used to recover sulfuric acid from solution.[121] This would allow for recycling of the acid with no solid residue created, at least from acid removal. This process could follow the above evaporation-crystallization process for recovery of ferrous sulfate. The residues from evaporation-crystallization may be roasted with carbon and air to yield iron oxide and sulfur dioxide.[121] This system is not yet being used, but may ultimately prove to be economical. The iron oxide could be sintered and used in the blast furnace. Sulfur dioxide has a ready market. This reaction:

(XIII-4) $2\ Fe\ SO_4 \quad H_2O + C + 1/2\ O_2 \longrightarrow Fe_2O_3 + 2\ SO_2 + 2\ H_2O + CO_2$

molecular weights $339.84 + 12.01 + 16 \qquad 159.70 + 128.14 + 36 + 44.01$

yields 128.14/339.84 or .377 kilograms of sulfur dioxide per kilogram of iron sulfate monohydrate residue from the evaporation-crystallization process.

The remaining miscellaneous water pollutants make no great contribution to solid residue management problems. The oils and greases from soaking pits, degreasing operations, etc. are not usually recycled. They may be removed from the water by flotation and coagulation in efficiencies approximating 75 percent. Emulsified oils in cold mill effluents may be reduced by 75 to 80 percent by recirculation of the soluble oil solutions.[151] Hot-rolling mill effluents are usually treated with plain sedimentation techniques, removing only 20 percent of all effluent oil.[151] The trend toward coagulation should increase oils removal to approximately 80 percent.[151] These oils are sometimes reprocessed for either reuse in mill operations or for sale.[90]

Phenols, cyanides, and ammonia from blast furnaces and coke plant effluent can be treated effectively. Phenols may be reduced by 81 percent, cyanides by 98 percent, and ammonia by 99 percent if coke is quenched with benzol plant and still wastes, and all cooling water is recirculated. The pollutants stick to the coke and are subsequently burned in the blast furnace.[90]

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Reuse of residues reclaimed from air and water pollution control devices was partially covered in the section on pollution treatment processes. That information is summarized in Table XIII-9 under description of residue. Almost no quantitative data exists for reuse levels in the steel industry. The percentages in Table XIII-9 can best be described as educated guesses and are, therefore, given a confidence level of 2, indicating a possible 50 percent variance.

Table XIII-10 presents a partial list of recovered by-products from blast furnaces and basic steel mills. The source, Pollution Control Technology, did not specifically list the emission factors or treatments used in deriving these estimates.[121] They can be taken as a basic guide to some possible recycling and sale opportunities.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

The final effects of air and water pollution control on solid residues are highly dependent upon the extent of recycling, the specific control techniques used, and the growth of pelletizing, direct reduction, and continuous casting. The effluent guidelines to be established for 1977 and 1983 should yield more detailed information on residue disposal techniques and the resultant total solid waste impact.

Taking an overall view, it is apparent that the weight of residues recovered from air and water pollution control in blast furnace and basic steel production is fairly significant in relation to total solid wastes. Many of these residues, however, are sold or recycled, thereby reducing the load upon solid wastes.

TABLE XIII-9
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 331

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Description/Disposal Residue
Coking - particulates	Beehive-by product	None	-	-
Coking - ammonia	All	Sulfuric acid scrubbing	30	$(NH_4)_2 SO_4$ sale or disposal
Reduction - particulates	Blast furnace	Filters and precipitators	80	Recycle to sinter or dispose to landfill
		Scrubbers	80	Suspended solids
Steel furnaces-particulates	Open hearth	Precipitators	80	Recycle to sinter or dispose to landfill
		Scrubbers	80	Suspended solids
	Basic oxygen furnace	Precipitators	80	Recycle to sinter or dispose to landfill
		Scrubbers	80	Suspended solids
	Electric arc furnace	Precipitators	80	Recycle to sinter or dispose to landfill
		Scrubbers	80	Suspended solids
Sintering - particulates	Blast furnaces & sinter plants	Scrubbers	90	Suspended solids
Sintering-suspended solids	Blast furnaces & sinter plants	Sedimentation	80	Recycle to sinter or dispose to landfill

TABLE XIII-9 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 331

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Description/Disposal Residue
Sintering - suspended solids		Coagulation and sedimentation	80	Recycle to sinter or dispose to landfill
		Recirc. and sedimentation	80	Recycle to sinter or dispose to landfill
		Recirc., sediment., and coag.	80	Recycle to sinter or dispose to landfill
Scarfing- particulates		Dry treatments	70	Recycle to sinter or dispose to landfill
		Wet treatments	70	Suspended solids
Material handling- particulates		Dry treatments	60	Recycle to sinter or dispose to landfill
		Wet treatments	60	Suspended solids
Rolling mill- suspended solids		Sedimentation,	70	Recycle to sinter or dispose to landfill
		coagulation and sedimentation	70	Recycle to sinter or dispose to landfill
		Recirculation and sedimentation	70	Recycle to sinter or dispose to landfill
		Recirc., sediment., and coag.	70	Recycle to sinter or dispose to landfill

TABLE XIII-9 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 331

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Description/Disposal Residue
Pickling-$FeSO_4$		Lime neut. with sedimentation	70	Iron oxide - recycle Calcium sulfate - sale or disposal
		Evaporation - crystallization	70	Ferrous sulfate crystals
		Crystal roasting	90	Iron oxide to blast furnace. Liquid SO_2 - sale
Pickling-H_2SO_4		Lime neut. with sedimentation	70	Calcium sulfate - sale or disposal Iron oxide - recycle
		Evaporation - crystallization	70	Sulfuric acid in original solution
		Dialysis	90	H_2SO_4 - regenerate

TABLE XIII-10[121]
BY-PRODUCT RECOVERY POTENTIAL IN BLAST FURNACES AND BASIC STEEL PRODUCTION

Process	By-product	Quantity	Value	Diminution of Pollutant Load
Coke plant ammonia liquor	Phenol	10.5 kg/ton coke	$0.22/ton coke	40%
	Ammonia sulfate	12 kg/ton coke	$1.10/ton coke	50%
	Ammonia	4 kg/ton coke	$0.24/ton coke	50%
	Napthalene Benzene Xylene Cresols	10 kg/ton coke	$2.20/ton coke	100%
Pickle liquor	Iron oxide	25-25 kg/ton iron	$.11-.22/ton iron	100%
	Gypsum	20-25 kg/ton iron	$.11-.22/ton iron	100%
	Sulfuric acid	15-20 kg/ton iron	$.66-.88/ton iron	100%
	Hydrochloric acid	15-20 kg/ton iron	$.66-.88/ton iron	100%
Blast furnace scrubber waters	Mill scale	10-25 kg/ton iron		60-80%

Efficiencies are improving in steel mills. Table XIII-11shows the quantities of inputs or outputs in a typical blast furnace in 1961. By 1975 the requirement for coke in one metric ton of pig iron production was forecast to decline to 600-650 kilograms.[155] Recent developments confirm this forecast.

Most furnaces produce 15 to 65 kilograms of particulates per metric ton of iron. Much of the slag is recycled to sintering processes along with the particulates, which indicates that the contribution to solid wastes of air pollution control in blast furnaces may be around 10 percent. The residues from pollution control in steel furnaces and hot rolling mills decrease this proportion,as few solid wastes are generated in these processes. Coking wastes are largely recycled or lost to the environment and so do not contribute substantially to solid wastes. Pickling and scarfing wastes are generally sent to landfills and, therefore, make significant contributions to solid wastes. Direct reduction will very significantly reduce the residue load from pollution control. The amount of residues in this process will largely be a function of the fuel used, since coking is not needed. Continuous casting, because of its higher efficiency (95 percent or 85 percent for batch casting), may also reduce solid residues.

Tables XIII-12-15 provide estimates of the total residues from air and water pollution control for 1971, 1975, 1980 and 1985. The estimates are shown for air and water separately. Since particulates from coking are uncontrolled, no solid waste from air pollution treatment results; thus particulates from coking are not included in Tables XIII -12 -15. The water estimates contain most of the residues from air pollution control, since water scrubbers have been the common method of cleaning gaseous emissions. Also, some of the precipitators have been flushed with water. Sulfuric acid scrubbing of coke plants creates ammonium sulfate, which also precipitates in water. Thus, to add the residues to both air and water would involve counting them twice.

The water estimates are derived independently except for steel, which accounts for 95 percent of the total residues from air pollution control. The total solid waste residues from air and water pollution control residues have been indicated at the end of each year. These are the total of the particulate control in scarfing and sulfuric acid scrubbing for the coke ovens plus the total water pollution control residues. Due to the uncertainty involved in the prediction of treatment processes and reuse levels, the results presented in this section have been given a confidence level of 2, indicating a possible 50 percent variance.

Composition of Solid Waste Residues from Air and Water PollutionTreatment Processes.

Figures specifying the physical and chemical composition of solid waste generated by air and water pollution control of steel furnaces and of the pickling process are listed in Tables XIII-16 and XIII-17. The figures for steel furnace particulates show that these emissions are reasonably dry, inert, non-biodegradable, and contain no hazardous substances. This is generally true for all the particulate and suspended solid pollutants

TABLE XIII-11[155]
BLAST FURNACE INPUT AND OUTPUT, 1961

Inputs	Metric Tons
Iron ore	1.7
Coke	0.9
Limestone	0.4
Cinder, scale, and scrap	0.2
Air	4-4.5
Outputs	
Pig iron	1.0
Slag	0.5
Exhaust gases	~6.0

TABLE XIII-12
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates (residues included in water pollution treatments):[a]								
Reduction	Blast furnace	Filters & precipitators	50	(2,400)	73	(1,760)	To water treatment	
		Scrubbers	50	(2,400)	73	(1,760)		
Steel furnace	Open hearth	Precipitators	50	(150)	73	(110)		
		Scrubbers	50	(150)	73	(110)		
	Basic oxygen	Precipitators	50	(790)	73	(580)		
		Scrubbers	50	(790)	73	(580)		
	Electric arc	Fabric filters	100	(170)	73	(120)		
Sintering		Scrubbers	100	(880)	73	(650)		
		Total		(7,730)	73	(5,620)		(5,620)
Particulates (residues not included in water pollution treatments):[a]								
Materials handling		Precipitators	100	540	30	640	40	250
Scarfing		Precipitators	50	80	73	60	30	20
		Scrubbers	50	80	73	60	30	20
Ammonia:								
Coking		Sulfuric acid scrubbing	100	790	30	240	70	170
Total Residues not Included in Water Pollution Treatments:				1,490	73	1,000	19	460
Total Residues from Air Pollution Control:				(9,220)	72	(6,620)		(6,080)

TABLE XIII-12 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 331

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
Reduction	Blast furnace	Controls from Table XIII-7	100	2,460	95.8	2,360	20	470
Steel furnaces			100	3,780	95.8	3,620	20	720
Sintering			100	480	95.8	460	20	90
Hot rolling mills			100	4,580	93.6	4,280	30	1,280
		Total		11,300	95	10,720	24	2,560
Pickle liquors								
Pickling	H_2SO_4	Neutralization, sedimentation	50	100	80	80	30	25
		Evaporation, crystallization	50	60	95	60	30	20
	Fe_2O_4	Neutralization, sedimentation	50	320	80	260	30	80
		Evaporation, crystallization	50	260	95	240	30	70
		Total		740	86.5	640	30	190

TABLE XIII-12 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total Residues from Water Pollution Control :				12,040	94	11,360	24	2,750
Total Residues from Air and Water Pollution Control:				13,530	86	12,160	22.5	3,210

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[a] The water pollutant data presented below include all scrubber effluents from the above operations. Since many precipitators are flushed with water in steel and blast furnaces, the entire total of the above residues is assumed to be included in the water pollutant estimates below from the Cost of Clean Water. Although the Cost of Clean Water does not specifically cite all sources of the water pollutants in the effluent, it is clear from a reading of this source that reduction, sintering, and steel furnace air pollutants are included.

TABLE XIII-13
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates (residues included in water pollution treatments):[a]								
Reduction	Blast furnace	Filters & precipitators	50	(2,850)	90	(2,570)	To water treatment	
		Scrubbers	50	(2,850)	90	(2,570		
Steel furnace	Open hearth	Precipitators	50	(90)	90	(80)		
		Scrubbers	50	(90)	90	(80)		
	Basic oxygen	Precipitators	50	(1,020)	90	(920)		
		Scrubbers	50	(1,020)	90	(920)		
	Electric arc	Fabric filters	100	(380)	90	(340)		
Sintering		Scrubbers	100	(800)	90	(720)		
		Total		(9,100)		(8,200)		(8,200)
Particulates (residues not included in water pollution treatments):[a]								
Materials handling		Precipitators	100	690	40	260	40	100
Scarfing		Precipitators	50	100	90	90	30	30
		Scrubbers	50	100	90	90	30	30
Ammonia:								
Coking		Sulfuric acid scrubbing	100	730	40	260	70	180
Total Residues not Included in Water Pollution Treatments:				1,620		700		340
Total Residues from Air Pollution Control:				(10,720)		(8,900)		(1,900)

TABLE XIII-13 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
Reduction	Blast furnaces	Controls of Table XIII-7	100	2,920	100	2,800	20	560
Steel furnaces			100	2,950	100	2,840	20	570
Sintering			100	430	100	410	20	80
Hot rolling mills			100	5,800	90	5,450	30	1,630
		Total		12,100	100	11,500	20	2,840
Pickle liquors:								
Pickling	H_2SO_4	Neutralization, sedimentation	40	110	80	90	30	25
		Evaporation, crystallization	60	80	100	80	30	25
	Fe_3O_4	Neutralization, sedimentation	40	360	80	290	30	90
		Evaporation, crystallization	60	360	100	340	30	100

TABLE XIII-13 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
		Total		910	90	800	30	240
Total Residues from Water Pollution Control:				13,010	90	12,300	20	3,080
Total Residues from Air and Water Pollution Control:				14,630	90	13,000	20	3,420

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[a] See footnote (a), Table XIII-12

TABLE XIII-14
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates (residues included in water pollution treatments):[a]								
Reduction	Blast furnace	Filters & precipitators	50	(3,470)	100	(3,400)	To water treatment	
		Scrubbers	50	(3,470)	100	(3,400)		
Steel furnace	Open hearth	Precipitators	50	(70)	100	(70)		
		Scrubbers	50	(70)	100	(70)		
	Basic oxygen	Precipitators	50	(1,060)	100	(1,040)		
		Scrubbers	50	(1,060)	100	(1,040)		
	Electric arc	Fabric filters	100	(560)	100	(550)		
Sintering		Scrubbers	100	(670)	100	(660)		
		Total		(10,430)		(10,230)		(10,230)
Particulates (residues not included in water pollution treatments):[a]								
Materials handling		Precipitators	100	780	50	380	40	150
Scarfing		Precipitators	50	120	100	120	30	35
		Scrubbers	50	120	100	120	30	35
Ammonia:								
Coking		Sulfuric acid scrubbing	100	890	40	380	70	260
Total Residues not Included in Water Pollution Treatments:				1,910	100	1,000	20	470
Total Residues from Air Pollution Control:				(12,340)	90	(11,230)	20	(2,450)

TABLE XIII-14 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
Reduction	Blast furnaces	Controls from Table XIII-7	100	3,560	100	3,450	20	690
Steel furnaces			100	3,910	100	3,780	20	760
Sintering			100	360	100	350	20	70
Hot rolling mills			100	6,590	90	6,240	30	1,871
		Total		14,420	100	13,820	20	3,390
Pickle liquors:								
Pickling	H_2SO_4	Neutralization, sedimentation	40	110	80	90	30	30
		Evaporation, crystallization	60	110	100	100	30	30
	Fe_3O_4	Neutralization, sedimentation	40	370	80	300	30	90
		Evaporation, crystallization	60	440	100	420	30	130

TABLE XIII-14 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 331

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Pickle liquors: (Cont.)								
		Total		1,030	90	910	30	280
Total Residues from Water Pollution Control:				15,450	100	14,730	20	3,670
Total Residues from Air and Water Pollution Control:				17,360	100	15,730	23	4,140

TABLE XIII-15
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 331

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates (residues included in water pollution treatments):[a]								
Reduction	Blast furnace	Filters & precipitators	50	(3,480)	≈100	(3,410)	To water treatment	
		Scrubbers	50	(3,480)	≈100	(3,410)		
Steel furnace	Open hearth	Precipitators	50	(60)	≈100	(60)		
		Scrubbers	50	(60)	≈100	(50)		
	Basic oxygen	Precipitators	50	(1,210)	≈100	(1,190)		
		Scrubbers	50	(1,210)	≈100	(1,190)		
	Electric arc	Fabric filters	100	(660)	≈100	(640)		
Sintering		Scrubbers	100	(580)	≈100	(570)		
		Total		(10,740)		(10,520)		(10,520)
Particulates (residues not included in water pollution treatments):[a]								
Materials handling		Precipitators	100	880	70	610	40	240
Scarfing		Precipitators	50	130	100	130	30	40
		Scrubbers	50	130	100	130	30	40
Ammonia:		Sulfuric acid scrubbing	100	890	50	450	70	310
Total Residues not Included in Water Pollution Treatments:				2,030		1,320	50	630
Total Residues from Air Pollution Control:				(12,770)	90	(11,840)	20	(2,640)

TABLE XIII-15 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 331

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Suspended solids:								
Reduction	Blast furnace	Controls from Table XIII-7	100	3,560	100	3,460	20	690
Steel furnaces			100	4,240	100	4,120	20	820
Sintering			100	310	100	4,120	20	60
Hot rolling mills			100	7,350	100	6,980	.30	2,100
		Total		15,460	100	18,680	20	3,670
Pickle liquors:								
Pickling	H_2SO_4	Neutralization, sedimentation	40	120	80	100	30	30
		Evaporation, crystallization	60	120	100	110	30	35
	Fe_3O_4	Neutralization, sedimentation	40	410	80	330	30	100
		Evaporation, crystallization	60	490	100	470	30	140
		Total		1,140	90	1,010	30	300
Total Residues from Water Pollution Control:				16,600	100	15,870	20	3,970
Total Residues from Air and Water Pollution Control:				18,630	100	17,190	20	4,600

TABLE XIII-16
COMPOSITION OF SOLID WASTE RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 331

Item: Steel Furnaces – Particulates

Process or Activity: Open Hearth, Basic Oxygen and Electric Arc

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Source/ Ref. No.
Weight (wet)	Kg	1	b
Volume (wet)	l	0.05	c
H_2O content (of wet weight)	%	-	n.d.[a]
Combustible	Kg	-	
Non-combustible	Kg	1	
Ash content	Kg	0.70	d
Liquid form	Kg		
Solid form	Kg	1	
Energy content	K cal	-	
Oxygen requirements	Kg BOD	-	
Valuable metals	Kg	0.30	d
Volatile	Kg	-	
Radioactivity	Curies	0	
Radioactive material	Kg	0	
Toxic chemicals	Kg	-	
Pesticides	Kg	0	
Pathogens	Kg	0	
Explosives	Kg	0	
Corrosives	Kg	-	
Liquid hydrocarbons	Kg	-	
Biodegradable	Kg	-	
Non-biodegradable	Kg	-	

TABLE XIII-16 (Cont.)
COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 331

[a] n.d. = no data.

[b] All residues assumed to be dry.

[c] Calculated from a density for steel furnace particulates of 2 gram/cc.

[d] Steel furnace particulates assumed to be approximately 30 percent iron and 70 percent ash and other forms of carbon. With 10 to 15 percent void space, this sums up to the density specified in c above.

TABLE XIII-17
COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 331

Item: Pickling
Process or Activity: Lime Neutralization

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Source/ Ref. No.
Weight (wet)	Kg	1.15	b
Volume (wet)	l	43.	c
H_2O content (of wet weight)	%	6.75	b
Combustible	Kg	-	n.d.[a]
Non-combustible	Kg	1.15	d
Ash content	Kg	0	
Liquid form	Kg	0.15	b
Solid form	Kg	1	b
Energy content	K cal	-	
Oxygen requirements	Kg BOD	-	
Valuable metals	Kg	0.25	e
Volatile	Kg	-	
Radioactivity	Curies	-	
Radioactive material	Kg	-	
Toxic chemicals	Kg	-	
Pesticides	Kg	-	
Pathogens	Kg	-	
Explosives	Kg	-	
Corrosives	Kg	0.15	f
Liquid hydrocarbons	Kg	-	
Biodegradable	Kg	-	
Non-biodegradable	Kg	1.15	g

TABLE XIII-17(Cont.)
COMPOSITION OF SOLID WASTE RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 331

[a] n.d. = no data.

[b] Estimated based on proportions of gypsum and iron oxide generated per unit of pickling liquor treated (as given in section on water pollution control , p25, this Section) coupled with an estimate of contained liquid based on a particle size of 1 mm with particles closest packed and all pore space filled.

[c] Calculated directly from assumptions of b (above) coupled with well-known densities for various compounds.

[d] All constituents assumed non-combustible.

[e] Based on Pollution Control Technology estimates of iron oxide and gypsum produced per metric ton of iron processed.

[f] Based on assumptions in b (above) and also assuming that almost all liquid present will be partially unreduced H_2SO_4.

[g] All constituents assumed non-biodegradable.

listed in Table XIII-6.

The figures for the lime neutralization process for treating waste pickling liquor can be considered typical of the other main category of steel mill solid waste. These are wastes that have a significant percentage of their weight made up by corrosive or toxic chemicals, but are generated in much smaller volumes than the particulates and suspended solids. Estimates in this section are questionable, since there is a dearth of available data on the composition of solid waste residues from air and water treatment processes. The figures are based on knowledge of the composition of the waste being treated, and are assigned a confidence level of 2, indicating a possible 50 percent variance.

Factors Affecting Quality of the Data.

In the indication of each confidence level, the deficiencies in the necessary data were alluded to. In general, the deficiencies were of three forms. In some cases, quantitative data did not exist. This is true of reuse data and treatment process residue composition data. Data which did exist quite often showed an extremely wide variation among the results of different investigators. This was the case for untreated discharge estimates and production forecast data. Finally, in the case of treatment process forecasts, the existing data were too general to be of much assistance. However, the deficient data were utilized to the fullest possible extent to reduce the amount of interpolation and extrapolation needed. The results are considered accurate within the confidence levels stated. The overall confidence levels for forecasts of solid waste resulting from pollution control in SIC 331 may be given a confidence level of 2, indicating a possible 50 percent variation in the data.

Summary.

Untreated Discharges. The Blast Furnace and Basic Steel Industry is a significant contributor to both uncontrolled air pollution (particulates, hydrocarbons, and carbon monoxide) and uncontrolled water pollution (suspended solids). Significant quantities of particulates are generated from steel furnaces (especially basic oxygen), and during coking, reduction, scarfing, and sintering. Large quantities of suspended solids are discharged to water during blast furnace reduction and sintering, and from steel furnaces and rolling mills. Iron sulfate and sulfuric acid are generated in significant quantities during pickling. Total uncontrolled particulate discharges from SIC 331 were forecast to increase to 18.6 billion kg in 1985 from 14.4 billion kg in 1971; uncontrolled SS discharges were forecast to increase from 11.3 to 15.4 billion kg during the same period.

Treatment Methods and Reuse. The main treatment methods that were forecast to be used to control particulate and other air pollutant discharges in blast furnaces are fabric and other filters and precipitators. Control of particulate emissions from steel furnaces can be economically accomplished through wet scrubbers as well as fabric filters and precipitators. Medium energy wet scrubbers are sufficient for particulate control during sintering. Suspended solids generated from blast furnaces and rolling mills and during sintering can be controlled through a combination of recirculation, coagulation, and sedimentation. Iron sulfate and sulfuric acid in pickle liquor can be removed through lime neutralization followed by sedimentation, evaporation followed by crystallization, or dialysis. Potential reuse of pollutants in blast furnaces and steel mills is high. Seventy to ninety percent of the following pollutants were estimated to be reused currently: particulates from reduction, steel furnaces, sintering, and scarfing;suspended solids from sintering and rolling mills; and iron sulfate and sulfuric acid from pickling.

Residues Generated from Pollution Control: Types and Amounts. Total solid residues generated from air and water pollution control in blast furnaces and basic steel mills were forecast to increase from 3,020 million kg in 1971 to 4,600 million kg in 1985. Most of these residues will be derived from water pollution control; this includes particulates transferred to water from air pollution controls (scrubbers and precipitators). The main sources of these residues will be particulates generated from blast furnaces and basic oxygen steel furnaces, and suspended solids generated from hot rolling mills. The residues generated from steel furnace pollution control will be fairly dry, inert, and non-biodegradable, and will contain no hazardous substances. Solid residues generated through lime neutralization during pickling will tend to be more corrosive and toxic, but these are a relatively minor contribution to total residues generated.

SECTION XIV
THE IRON FOUNDRY AND FERROALLOY INDUSTRIES
SIC 3313, 332

Introduction.

Iron foundries produce castings from gray iron, iron scrap, and pig iron. These castings are used in machine and vehicle parts. Cupola furnaces, which produce about 85 percent of all castings,[89] are the major pollutant source in the industry.[91]

Ferroalloys are iron, alloyed mainly with silicon, manganese, or chromium. This Section considers only the production of the alloying material itself and not the production of alloyed steel, which is covered in Section XIII. Electric smelting furnaces produce over 75 percent of all ferroalloys and are the major source of particulate emissions from the industry.[169]

Untreated Discharge Factors.

Table XII-1 lists uncontrolled discharge rates for iron foundries and ferroalloys. Most foundry air pollutant emissions are from metal melting operations.

Air Pollutants. The production of 13.0×10^6 kkg of gray iron generates 197×10^6 kg of particulates,[89] at the present average removal efficiency for particulates, 12 percent. The untreated particulate discharge factor can then be calculated as 17.2 kg per metric ton of metal produced. Similar data for metal production and materials handling[10] yields a figure of 10.6 kg of particulates per metric ton of metal produced fromiron foundries, 205 kg particulates per metric ton for ferroalloys from blast furnaces, and 125 kg particulates per metric ton for electric furnace production and materials handling in the ferroalloy industry. The confidence level for untreated air pollutant discharge factors is 3, indicating ± 25 percent possible variation in the data.

Water Pollutants. The industries under consideration produce small amounts of water pollutants, mainly oil, phenols, cyanide, and various metallic ions. The quantities produced are small relative to particulates produced and are insignificant with respect to total solid waste generated; water pollutants and solid waste generated from water pollution control (except those transferred to water from particulate control) are therefore not further considered in this Section.

Industry Description and Schematic.

Iron foundries utilize four different furnace types: electric arc, electric induction, reverberatory, and cupola; the latter accounts for 85 percent of casting. The metal charge in cupola furnaces is melted by burning coke in direct contact with the metal. Most of the particulate emissions from foundry operations result from this melting

TABLE XIV-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 3313,332

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Iron foundries	Furnace & mat.handling	kkg metal	Particulates	17.2	89
Ferroalloys	Electric furnace & mat. handling	kkg ferroalloy	Particulates	125	10
	Blast furnace			205	10

process.[89] Ferroalloys are produced mainly in blast furnaces or electric smelting furnaces. The type of process used depends partially on the alloy being produced, but the common alloys are usually produced in electric furnaces. Raw ore, coke, and limestone or dolomite are mixed in electric furnaces and melted either by electric arc or resistive heating. The major ferroalloys produced are ferrosilicon (50 to 98 percent silicon), ferrochromium in various grades, ferrochrome silicon, and ferromanganese. Ferroalloys are used mainly for deoxidation and alloying of steel and cast iron, but there are other uses such as the use of 75 percent ferrosilicon as a reducing agent in the production of metallic magnesium.[118] Both electric and blast furnaces produce substantial quantities of particulates.

Figure XIV-1 presents a general industry process schematic for both the iron foundry and ferroalloy industries.

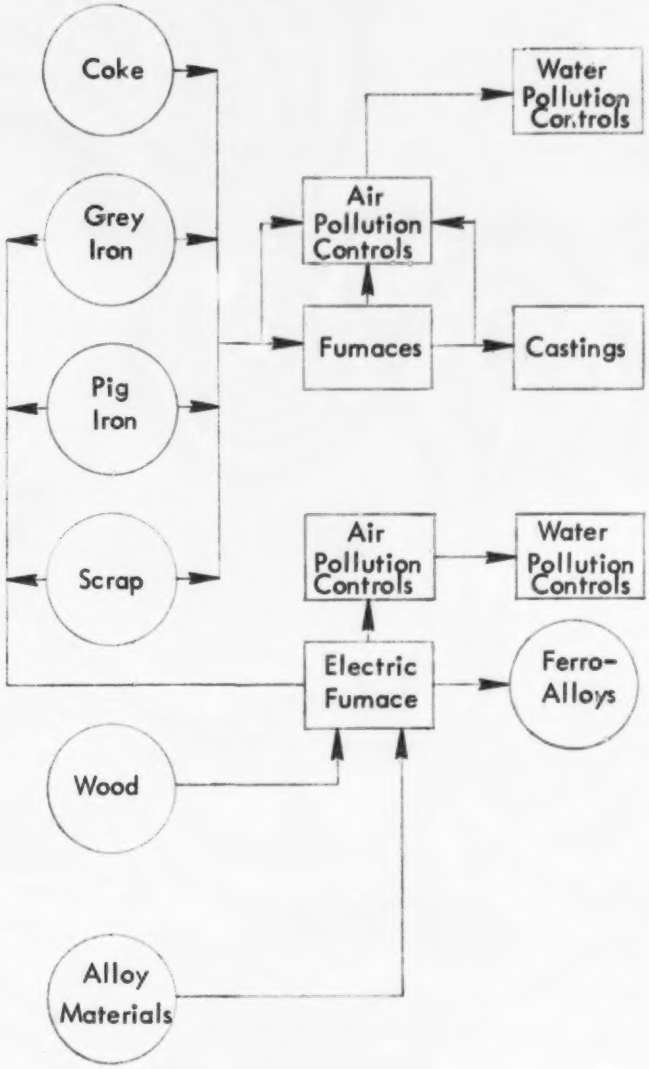
Economic Forecasts.

Growth in iron foundry and ferroalloy production, as is the case in the basic steel industry discussed in Section XIII, is closely related to American economic growth. Table XIV-2 lists available economic forecasts for the iron foundry and ferroalloy industries, Table XIV-3 forecasts production for the years 1971, 1975, 1980, and 1985.

Ferroalloy shipments have remained constant since 1967 at about 2.3×10^6 kkg;[431] the number of ferroalloy plants is expected to remain constant through 1985.[431] Imports constitue a great portion of ferroalloy consumption.[431] It is assumed that the total amount of ferroalloys produced will remain approximately constant at 2.3 to 2.6×10^6 kkg until 1985. The production of ferroalloys in blast furnaces is assumed to decrease, continuing the trend apparent for the period between 1955-1970.[347] Blast furnace ferroalloy production is forecast to decrease from 346,000 kkg in 1970 to 150,000 kkg in 1985.

Shipments of ferrous castings are expected to show a relatively large growth trend, increasing from 15 million kkg in 1971 to 22 million kkg in 1980. This forecast reflects expected growth in the GNP, particularly increases among the main customer industries for ferrous castings, i.e., automobiles, construction machinery, railroad cars, machine tools and steel products. Steady advances in these customer-industries represent an ever increasing demand for iron and steel castings. Industry sources show even greater optimism in their forecasts by projecting a 5 year increase in production (1972-1977) of 23.6 percent, an annual growth rate of 4.5 percent.[68] Within this industry forecast, it is expected that production by type of metal cast will vary considerably; ductile and malleable iron castings are forecast to grow at an annual rate of approximately 6 percent.

The most notable trend in the foundry industry appears to be a growing tendency to shift from smaller, highly-polluting foundries to larger mechanized and improved facilities.[83] The cupola furnace is forecast to maintain its dominant share of total output.



Coke
Grey Iron
Pig Iron
Scrap
Wood
Alloy Materials
Water Pollution Controls
Air Pollution Controls
Fumaces
Castings
Air Pollution Controls
Water Pollution Controls
Electric Fumace
Ferro-Alloys

FIGURE XIV-1
INDUSTRY SCHEMATIC:
IRON FOUNDRIES AND
FERROALLOYS

TABLE XIV-2
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 3313, 332

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Ferrous castings	Shipment	10^6 kkg	1972	16.4	14.8				83	1973
			1973	16.9						
Ferroalloys	Electric furnace	10^6 kkg	1970	2.3					431	1973
Ferroalloys	Blast furnace	10^6 kkg	1955	0.846					347	1972
			1960	0.761						
			1965	0.612						
			1968	0.502						
			1969	0.420						
			1970	0.346						

TABLE XIV-3
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 3313, 332

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Iron castings		10^6 kkg	14.9	83	17.3	a	22.1	a	28.3	a
Ferroalloys	Electric furnace	10^6 kkg	2.0	b	2.0	b	2.1	b	2.4	b
	Blast furnace	10^6 kkg	0.33	b	0.28	b	0.22	b	0.15	b

[a] Based on assumptions in text. The growth rate from 1971 to 1975 is 4 percent per year which increases to 5 percent per year from 1975 to 1983.

[b] Based on approximately constant total ferroalloy production from Ref. 431 with an increasing percentage accounted for by electric furnaces from Ref. 347.

The forecasts in this section have a confidence level of 2, indicating a ± 50 percent variation in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table XIV-4 presents forecasts of total air pollutant discharges before treatment by the iron foundry and ferroalloy industries for selected years through 1985. The forecasts were obtained by multiplying the untreated discharge factors by the projected future productions. Total particulate emissions before treatment are forecast to increase over the period 1971 to 1985 from 573×10^6 kg to 818×10^6 kg. The confidence level is 2 for particulate discharge estimates, indicating a possible 50 percent variation in the data.

Likely Pollution Treatment Processes.

The low level of particulate control for iron foundries (12 percent in 1967) reflects the limited use of scrubbers and fabric filters on cupolas.[89] The 90 percent removal required for iron foundries by 1977 will most likely be achieved by using wet scrubbers (with 70 to 95 percent efficiency) or baghouses (up to 99 percent efficiency).[89,169] Available data indicate that approximately 40 percent control has been achieved in electric furnace production of ferroalloys[10] out of a maximum possible 75[121] to 80[10] percent (achievable with spray towers[121]). Available data also indicate that a 99 percent control has been achieved in blast furnaces.[10] It seems likely that all of the ferroalloys produced using electric arc furnaces will achieve at least an 80 percent control level by 1977, with either spray towers or to a greater extent baghouses.

Efficiency levels and solid residue impacts of the various air and water pollution treatment processes are presented in Table XIV-5. A generalized schematic for these processes appears in Figure XIV-2. The confidence level for the treatment process efficiences and residue ratios in this section is 4, indicating only a possible 10 percent variation in the data.

Reuse Potential for Solid Waste Residues from Pollution Treatment Processes.

In iron foundries, most of the air pollutants collected by pollution control equipment are generally not reusable.[91] However, personal communications with the industry[296] revealed that some plants are able to sell air pollution control residues to cement plants or to fertilizer plants as trace minerals. Because of the general lack of available reuse data,the confidence level in this Section is 1, reflecting a variation of at least 100 percent in the data. Table XIV-6 summarizes this information.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables XIV-7 through XIV-10 forecast the solid residue weights produced from pollution control activities for the years 1971, 1975, 1980, and 1985. Total residues are forecast to increase from 130×10^6 kg in 1971 to 650×10^6 kg in 1985. This

TABLE XIV-4
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 3313, 332

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Particulates:						
iron foundries	All	89	256	297	380	487
Ferroalloys	Blast furnace	10	67	57	45	31
	Electric furnace	10	250	250	263	300
			—	—	—	—
Total			573	604	688	818

TABLE XIV-5

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 3313, 332

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Iron foundries	All	Particulates	Scrubbers	90	1		169
			Baghouses	90	1		11,169
Ferroalloys	Electric furnace	Particulates	Spray tower	80	1		10,121
	Blast furnace	Particulates	Wet scrubber	99	1		10,121
Ferroalloys	All	Particulates	Baghouse	98	1		347
Iron foundries & ferroalloys	Wastewater from air pollution control	Suspended solids	Coagulation & settling	70-100	1		346
			Ponding	100	1		346

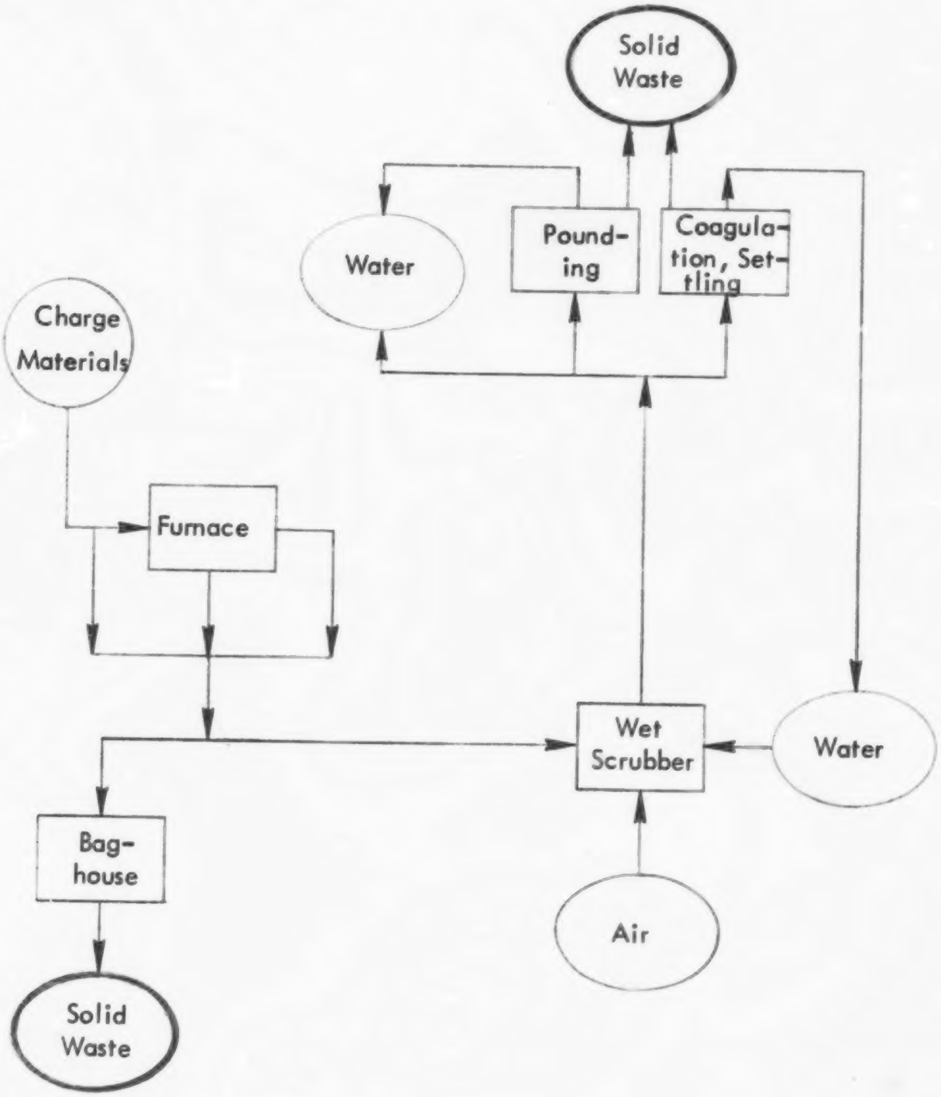

Solid Waste
Water
Pound- ing
Coagula- tion, Set- tling
Charge Materials
Furnace
Wet Scrubber
Water
Bag- house
Air
Solid Waste

FIGURE XIV-2
GENERALIZED TREATMENT SCHEMATIC:
IRON FOUNDRIES AND FERROALLOYS

TABLE XIV-6
REUSE POTENTIALS FOR SOLID WASTE RESIDUES
PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 3313, 332

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Particulates:					
Foundries			30	296	Slag may be sold to cement plants,
Ferroalloys			30	296	or to fertilizer plants as trace minerals
SS (from particulate control):					
Foundries			0	296	Sludge to class I landfill
Ferroalloys			0	296	Sludge to class I landfill

TABLE XIV-7
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 3313, 332

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Iron foundries		Baghouse	7	18	90	16	70	11
		Wet scrubber	7	(18)[a]	90	(16)	to SS water treatment	
		None	86	0				
Ferroalloys	Blast furnace	Scrubber	100	(67)	99	(66)	to SS water treatment	
	Electric furnace	Wet scrubber	32	(80)	80	(64)	to SS water treatment	
		Dry collector	38	95	98	93	70	65
		None	30	0				
		Total		(278)	92	(255)	87	(222)
Total Residues from Air Pollution Control:				113	96	109	70	76
WATER POLLUTANTS								
Suspended Solids:								
Iron foundries & ferroalloys	Waste water from air pullution control	Flocculation & settling	50	73	70	51	100	51
		None	50	0				
Total Residues from Water Pollution Control:				73	70	51	100	51
Total Residues from Air and Water Pollution Control:				278	64	179	71	127

TABLE XIV-7 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC 3313, 332

[a] Residues created during scrubbing are transferred to water as suspended solids, where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid wastes appears in the water pollutant estimates, since no solid wastes are created until treatment occurs following intermedial transfer.

TABLE XIV-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 3313, 332

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Iron foundries		Baghouse	22	65	90	59	70	41
		Wet scrubber	22	(65)[a]	90	(59)	to SS water treatment	
		None	56	0				
Ferroalloys	Blast furnace	Wet scrubber	100	(57)	99	(56)	to SS water treatment	
	Electric furnace	Wet scrubber	32	(80)	80	(64)	to SS water treatment	
		Dry collector	38	95	98	93	70	65
		None	30					
		Total		(362)	91	(331)	86	285
Total Residues from Air Pollution Control:				160	95	152	70	106
WATER POLLUTANTS								
Suspended Solids:								
Iron foundries & ferroalloys	Waste water from air pollution control	Flocculating & settling	70	125	70	88	100	88
		None	30	0				
Total Residues from Water Pollution Control:				125	70	88	100	88
Total Residues from Air and Water Pollution Control:				362	66	240	81	194

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[a] See footnote (a), Table XIV-7.

TABLE XIV-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 3313, 332

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Iron foundries		Baghouse	50	190	90	171	70	120
		Wet scrubber	50	(190)[a]	90	(171)	to SS water treatment	
		None	0					
Ferroalloys	Blast furnace	Wet scrubber	100	(45)	99	(45)	to SS water treatment	
	Electric furnace	Wet scrubber	32	(84)	80	(67)	to SS water treatment	
		Dry collector	68	179	98	175	70	122
		None	0					
		Total		(688)	91	(629)	83	(525)
Total Residues from Air Pollution Control:				369	94	346	70	242
WATER POLLUTANTS								
Suspended Solids:								
Iron foundries & ferroalloys	Waste water from air pollution control	Flocculation & settling	100	283	70	198	100	198
		None	0					
Total Residues from Water Pollution Control:				283	70	198	100	198
Total Residues from Air and Water Pollution Control:				688	79	544	81	440

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[a] See footnote (a), Table XIV-7.

TABLE XIV-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985 SIC 3313, 332

				Weight in Kg × 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Iron foundries		Baghouse	50	243	90	219	70	153
		Wet scrubber	50	(243)[a]	90	(219)	to SS water treatment	
		None	0	0				
Ferroalloys	Blast furnace	Wet scrubber	100	(31)	99	(31)	to SS water treatment	
	Electric furnace	Wet scrubber	32	(96)	80	(77)	to SS water treatment	
		Dry collector	68	204	98	200	100	204
		None	0					
		Total		(817)	91	(746)	92	(684)
Total Residues from Air Pollution Control:				447	94	419	85	357
WATER POLLUTANTS								
Suspended Solids:								
Iron foundries & ferroalloys	Waste water from air pollution control	Flocculation & settling	90	294	90	265	100	265
		Ponding	10	33	90	30	100	30
Total Residues from Water Pollution Control:				327	90	295	100	295
Total Residues from Air and Water Pollution Control:				817	87	714	91	652

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[a] See footnote (a), Table XIV-7.

increase can be accounted for by the increasing proportion of particulates subject to controls between 1971 and 1985 in both iron foundries and ferroalloy production.

Both wet and dry particulate control systems will generate residues approximately the same in dry weight as that of the particulates caught. In 1971, 32 percent of the ferroalloy furnace capacity was controlled by wet systems, 38 percent by dry, and 30 percent was uncontrolled.[431] This 30 percent is forecast to install dry systems by 1977.

It is assumed for forecasting purposes that the control level of 12 percent in foundries in 1967 [89] was the same in 1971 and will increase linearly to a maximum of 90 percent by 1977. Similarly, the 40 percent control in electric-furnace ferroalloy plants in 1968[10] is assumed to increase to about 90 percent control in 1977,[89] remaining constant thereafter. In view of the strict effluent guidelines proposed for similar circumstances[343,346] it can be assumed that about 70 percent of the suspended solids (derived from particulate control) will be captured by 1977, and close to 100 percent by 1983.

Composition of Solid Residues from Pollution Treatment Processes.

The chemical composition of the furnace fumes is similar to that of the materials charged in these industries.[118] The predominant oxides are those of silicon, iron, magnesium, and manganese.[118] Chromium and heavy metal oxides may be present[118] and carbonaceous particles may be also found in the particulates.[91] The diameters of these particulates are usually from 0.05 to 0.5 microns. A rough approximation on the basis of the above data would be: particle density = 3.5 and voids = 40 percent. This would correspond to 2.1 kg per liter of medium-packed particles. The particle density is a rough average of SiO_2 density (2.7) and metal oxide densities (about 41).[347] The voids figure is a rough approximation based on packing spherical particles of 0.05 to 0.5 microns diameter.

Most of the particulates are fairly insoluble. The characterization of the dry particulate residues is summarized in Table XIV-11; residues resulting from wastewater treatment when dry, should be similar in composition to the dry particulates described in Table XIV-11.

TABLE XIV-11

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 3313, 332

Item: Iron Foundries and Ferroalloys

Process or Activity: Particulate Residues

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	1	
Volume	liters, dry	0.48	
H_2O content (of wet weight)	%	0	
Combustible	kg	0	
Non-combustible	kg	1	
Ash content	kg		
Liquid form	kg		
Solid form	kg	1	
Energy content	kcal	0	
Oxygen requirements	kg BOD_5		
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg		
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg		
Non-biodegradable	kg		

Factors Affecting Quality of the Data.

Available data on discharge factors before treatment and treatment efficiencies are fairly accurate and certainly more accurate than estimates of reuse percentages. Economic forecasts are particularly uncertain because recent economic fluctuations in the United States, Europe, and Japan cast doubt on estimates of imports and imports are a large percentage of domestic consumption. Data on reuse of residues from pollution treatments is scarce, although it is known that many air pollutant residues from this sector are not reusable. The overall confidence level for the solid waste impact of air pollution control in iron foundries and ferroalloy production is 1, indicating a possible 100 percent variation in the data.

Summary.

Untreated Discharges. Particulates are the only significant pollutants generated in the iron foundry and ferroalloy industry. The small amounts of water pollutants produced are negligible in comparison to particulate emissions and, therefore, are not considered in this Section. Most particulate emissions from iron foundries are from cupola furnaces (85 percent). Particulates from the ferroalloy industry originate from blast and electric furnaces and material handling. Total uncontrolled particulate discharges were forecast to increase from 570 million kg in 1971 to 820 million kg in 1985.

Treatment Methods and Reuse. To achieve a high degree of particulate removal (90 percent) in the iron foundry industry, baghouses and wet scrubbers will be used rather than less efficient fabric filters. Pollutants generated by ferroalloy production in electric furnaces can be better controlled with spray towers; in blast furnaces the control of 99 percent can be achieved. Data concerning reuse of residues are minimal, but some portion of the trapped particulates is saleable for cement production or as trace minerals for fertilizer.

Residues Generated from Pollution Control Types and Amounts. Total residues from air pollution control are forecast to increase from 130 million metric tons in 1971 to 650 million metric tons in 1985. Since reuse of the residues is not extensive, large quantities of solid waste have to be disposed to landfills. The large increase in residues from air pollution control forecast over the period 1971 to 1985 is largely due to the higher control level required in the future.

SECTION XV
PRIMARY AND SECONDARY SMELTING AND REFINING OF NONFERROUS METALS
SIC 333 AND 334

Introduction.

Two kinds of nonferrous metal industries are studied in this Section: primary metals (aluminum, copper, lead, and zinc) and recycled or secondary metals (aluminum, copper and related alloys, lead, and zinc). Bauxite refining (SIC 2319) is included in this Section. It generates relatively little air pollution but substantial water pollutants. The primary nonferrous metal industries, and to a lesser extent secondary industries, emit large quantites of particulates. Except for aluminum, primary nonferrous metal smelting and refining also contribute large discharges of sulfur oxides. Both the primary and secondary nonferrous metals industries consume a large quantity of energy for heating and electrolytic processes.

Untreated Discharge Factors.

Air Pollutants. The primary copper industry generates both particulates and sulfur oxides.[169] The industry requires about 4 kkg of ore concentrate to produce 1 kkg of copper metal. The roasting, smelting, converting, and refining processes generate 67.5 kg of particulates and 625 kg of sulfur oxides per metric ton of concentrate ore (refining does not generate sulfur oxides).[169]

The primary aluminum industry generates large quantities of particulates--about 40.0 kg per metric ton of aluminum produced. These particulates are valuable, however, and the extensive controls used to capture and recycle them reduce net emissions to a negligible level. The primary aluminum industry also generates about 40.0 kg of fluorides per metric ton of aluminum produced.

The primary lead industry generates particulates and sulfur oxides. About 2 kkg of concentrate ore are required to produce 1 kkg of lead metal. Most of the sulfur oxides are emitted during the roasting process; plant emissions are about 330 kg of sulfur oxides per metric ton of concentrate.[169]

The primary zinc industry also generates particulates and sulfur oxides. About 550 kg of sulfur oxides are emitted per metric ton of concentrate ore (most of these during the roasting process). Production of one metric ton of zinc metal requires about two metric tons of concentrate.

Particulate emissions from primary lead and zinc production are well controlled and no special additional controls will be required in the future.[89] Particulates from primary copper are also largely controlled. Particulates are the main emission from the secondary nonferrous metals industry. About 29.4 kg of particulates are produced for each metric ton of output. The main emissions from secondary aluminum are particulates and gaseous chlorine. Secondary copper produces fly ash, soot, smoke, and zinc oxide. In addition, old copper wire is recovered by burning the outer rubber or plastic coating in incinerators; 190 - 356 kg of particulates are generated per metric ton of wire.[247] The process also generates indeterminate amounts of sulfur compounds, hydrochloric acid, nitrogen oxides, and hydrocarbons. Secondary lead operations generate particulates (lead, lead oxides, and contaminants) and nitrogen oxides. The secondary zinc industry produces particulate emission of zinc oxide. Table XV-1 lists air pollutant discharge factors for the metal industries discussed in this Section.

Water Pollutants. The principal water pollutants generated by the nonferrous metals industry are "settled mud," suspended solids, and total dissolved solids. Data concerning water pollutant emissions in the industries under consideration are minimal. Table XV-2 lists known water pollutant discharge factors. Bauxite refining, particularly of Arkansas-type ore, produces settled mud. Suspended solids are produced during wet scrap milling of secondary aluminum, and both suspended and dissolved solids are produced when liquid coolants are employed for secondary aluminum.

The untreated discharge factors for air and water pollutants have a confidence level of 3, indicating a possible 25 percent variation in the data.

Industry Description and Schematic.

Primary Metals. The basic processes in the nonferrous metals industry (on which there are many variations) consist of separating the metal from the ore and using thermal or electrical energy to purify the separated metal. Separation may be facilitated by introducing fluxes or gases to the molten metal or metal compounds. Purification is not always necessary (for example, purification is not required when bronze or brass alloys are formed from secondary copper). Figure XV-1 presents a schematic of the processes involved in extracting the main nonferrous metals from their metal-nonmetal compounds.

Aluminum is extracted from the ore as aluminum hydroxide, leaving a "mud" residual. The hydroxide is calcined to alumina, Al_2O_3 (about 2 kkg of concentrate are required to produce 1 kkg of alumina). The alumina is melted and split electrolytrically in "pots," i.e. electrolytic cells. Fluxes of aluminum chloride or fluoride facilitate the electrolysis of Al_2O_3. The electrolytic cells require an input of 18,000 kwh per kkg of aluminum produced.[169]

The first processing step for copper, zinc, and lead ores is the concentration of the metals, mostly to a sulfides form. Then the sulfides are heated in roasters or sometimes directly in furnaces; the metals and metal oxides are left as residue and SO_X and particulates are emitted. Zinc, lead, and small amounts of toxic metals (cadmium, mercury) are commonly found together in the same ores or sulfides. Heat generates toxic emissions of these metals. The zinc and lead oxides are separated from each other during sintering. The zinc metal is then obtained directly by distillation (zinc and lead oxides are not as heat-stable as Al_2O_3) or by conversion to $ZnSO_4$ and

TABLE XV-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 333, 334

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Primary Copper:		kkg Cu produced			169
Roasting			Particulates	90	
Smelting, converting & refining				180	
Roasting			SO_X	120.0	
Smelting, convering & refining				2,380.0	
Primary Aluminum:		kkg Al produced			167
Smelting (electrolytic)			Fluorides	40.0	
	Horizontal stud Søderberg		Particulates	70.0	
	Vertical stud Søderberg			40.0	
	Prebaked			27.5	
	Average[b]			40.0	
	Overall		Fluorides	40.0	
Primary Lead:		kkg load produced	SO_X	660.0	169
			Particulates	420	89
Primary Zinc:		kkg zinc produced	SO_X	1,100.0	169
			Particulates	866	89
Secondary Nonferrous Metals:		kkg produced	Particulates	29.4[c]	89

---

[a] For 1971 or most recent available information.

[b] Weighted by 1971 production rates.

[c] Calculated on the basis that the manufacture of 2.4×10^6 tons in 1967 of secondary nonferrous metals generated 24×10^3 tons of particulates at control level.[89]

TABLE XV-2
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 333, 334

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Primary Copper:				n.d.[b]	
Primary Aluminum:					
Bauxite refining	Surinam ore	kg Al_2O_3 produced	Settled mud	0.33	342
	Jamaica ore			1.0	
	Arkansas ore			2.0	
Primary Lead:				n.d.	
Primary Zinc:				n.d.	
Secondary Aluminum:		kkg Al procuded			346
Scrap milling	Dry		SS, TDS	0	346
	Wet		SS	720	
Metal cooling	Coolant		TDS, SS	0.7	
	Air		TDS, SS	0	
Other Secondary Nonferrous metals:				n.d.	

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[a] For 1971 or most recent available information.

[b] n.d. = no data available.

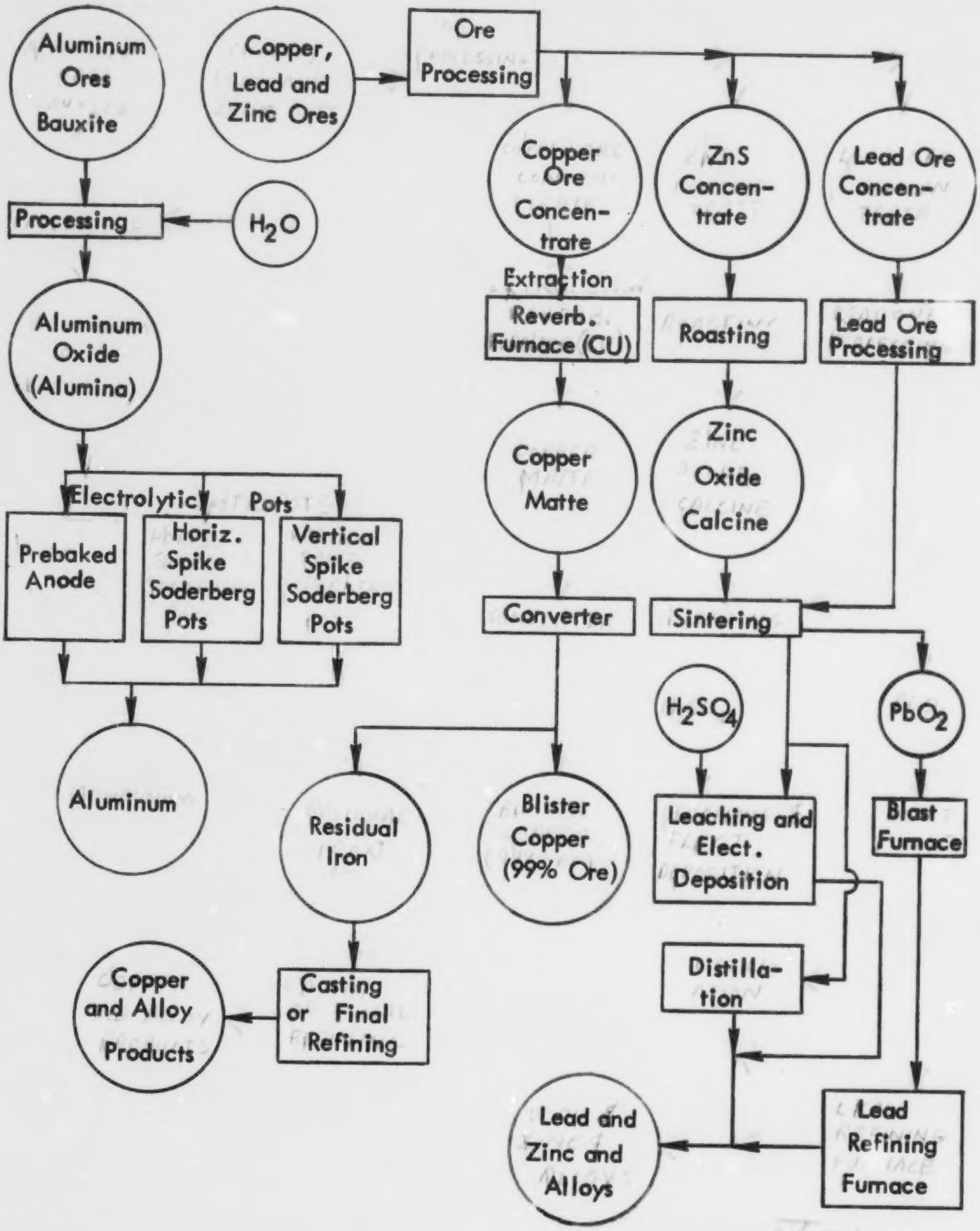
Aluminum Ores Bauxite
Copper, Lead and Zinc Ores
Ore Processing
Processing
H_2O
Copper Ore Concentrate
ZnS Concentrate
Lead Ore Concentrate
Extraction
Reverb. Furnace (CU)
Roasting
Lead Ore Processing
Aluminum Oxide (Alumina)
Copper Matte
Zinc Oxide Calcine
Electrolytic Pots
Prebaked Anode
Horiz. Spike Soderberg Pots
Vertical Spike Soderberg Pots
Converter
Sintering
H_2SO_4
PbO_2
Aluminum
Residual Iron
Blister Copper (99% Ore)
Leaching and Elect. Deposition
Blast Furnace
Distillation
Copper and Alloy Products
Casting or Final Refining
Lead and Zinc and Alloys
Lead Refining Furnace

FIGURE XV-1
INDUSTRY SCHEMATIC:
PRIMARY NONFERROUS METALS

subsequent electrolysis to metallic zinc. The lead is obtained from the lead oxide by thermal molecular fission in a furnace.

Secondary Metals. Two recovery processes are used in the secondary copper industry. 169 Secondary nonferrous metal smelting and refining is presented schematically in Figure XV-2. Aluminum scrap is milled wet or dry, or burned in a sweating furnace if plastics or other organic components are present in sizable quantity. The aluminum is then melted. It is usually treated with chlorine or aluminum fluoride flux to lower the magnesium content. The smelter is tapped and the aluminum and the slag are separated. In a manner similar to aluminum scrap, copper scrap is first incinerated if it has organic contaminants, or it is separated by electromagnetic or gravitational methods to separte iron-containing materials or other contaminats. The copper is then melted, and tin, zinc,or alloy may be added to produce copper alloys (e.g., brass, bronze).

Lead oxide, lead scrap, and lead slag from lead furnaces may be loaded into any of three types of furnaces: pot furnaces, for purest lead products; reverberatory furnaces, for semi-soft leads; and blast furnaces, for hard lead.

Zinc scrap may be melted directly; each metal in the scrap is removed at its melting range. Further refining of zinc can be done with retort distilling.

Economic Forecasts.

The output of primary and secondary nonferrous metals will roughly double between 1971 and 1985.[127] Table XV-3 lists available forcasts for various components of the industries under consideration, and Table XV-4 provides production forecasts for the years 1971, 1975, 1980, and 1985. No data are available on the proportions of different bauxite ore types that will be consumed in future years. It is assumed that the proportions will remain constant at 1973 ratios.

The production figures for primary metals production are generally available;[127] the production figures for secondary metals production are estimated by assuming that production of secondary aluminum, copper, and lead is,respectively, 22, 34, and 108 percent of primary production. The production of secondary zinc is assumed to be 21.8 percent of primary zinc consumption.

The confidence level for the economic forecasts is 3, indicating a possible variation of 25 percent in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Discharges of the main pollutants in the industries under consideration are given in Table XV-5. For secondary metals, the pollutants are particulates. For the primary metals, the main water pollutant is "settled mud," and the main air pollutant is SO_X. Part of the secondary metals' particulates may be captured by wet scrubbing systems.

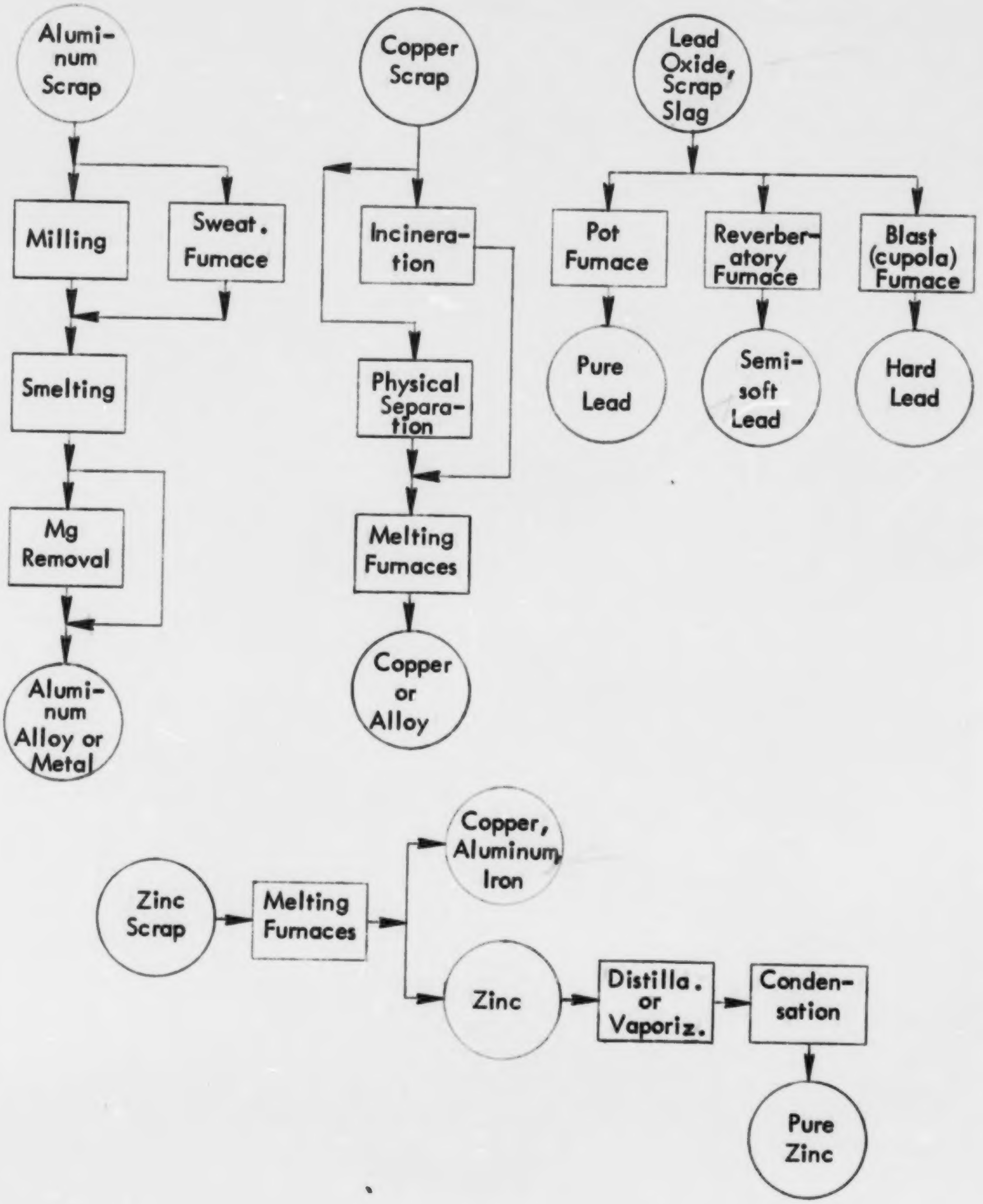
Aluminum Scrap
Milling
Sweat. Furnace
Smelting
Mg Removal
Aluminum Alloy or Metal
Copper Scrap
Incineration
Physical Separation
Melting Furnaces
Copper or Alloy
Lead Oxide, Scrap Slag
Pot Furnace
Reverberatory Furnace
Blast (cupola) Furnace
Pure Lead
Semi-soft Lead
Hard Lead
Zinc Scrap
Melting Furnaces
Copper, Aluminum Iron
Zinc
Distilla. or Vaporiz.
Condensation
Pure Zinc

FIGURE XV-2
INDUSTRY SCHEMATIC:
SECONDARY NONFERROUS
SMELTING AND REFINING

TABLE XV-3
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 333, 334

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Primary Aluminum		10^3 kkg Al			3,560	4,626	6,168	7,619	68	1973[a]
		10^3 kkg Al_2O_3			7,120	9,352	12,336	15,238		
	Surinam ore	Percent of production	1972-3	20					342	1973
	Jamaica ore	Percent of production	1972-3	64.2					342	1973
	Arkansas ore	Percent of production	1972-3	15.7					342	1973
	Smelting:									
	Horizontal Soderberg cell	Percent of production	1968	24.2					10	1971
	Vertical Soderberg cell	Percent of production	1968	21.2					10	1971
	Prebaked cell	Percent of production	1968	53.2					10	1971
	Refined	Total consumption	1973	2,041	1,824	2,268	2,540	2,813	68	1973
Primary (Slab) Zinc:	Consumption	10^3 kkg	1972 1974	1,296 1,361	1,138		1,540	1,724	127	1973

TABLE XV-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 333,334

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Primary (Slab) Zinc: (Cont.)	Production	10^3 kkg	1970	866	769				226	1972
		Ann. percentage growth	1969–75	3.9%					229	1972
			1975–80	1.9%					229	
			1970–90	1.0%					227	1971
	Production with domestic ores	10^3 kkg	1970	484				454	225	1972
Primary Lead:	Production	10^3 kkg	1970	605	590				228	1972
		Ann. percentage growth	1969–75	+ 2.1%					229	1972
			1975–80	+ 3.2%					229	1972
			1970–85	+ 1.0%					229	1971
	Production via domestic ores	10^3 kkg	1970	519			380		265	1972
	Sintering	Percent of total production	1968	100					310	1971
	Blast furnace	Percent of total production	1968	100					310	1971
	Dross reverb. furnace	Percent of total production	1968	100					310	1971

TABLE XV-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 333,334

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Lead:	Total consumption	10^3 kkg	1970	1,234	1,298				228	1972
			1972	1,296	1,298		1,495	1,631	68	1973
Primary Copper:	Production	Index	1970	100			130		337	1971
			1970-75	+ 4%					227	1971
			1975-80	+ 3.8%					227	1971
			1980-85	+ 3.6%					227	1971
	Reverb. furnace	Percent of total production	1968	100					10	1971
	Converters	Percent of total production	1968	100					10	1971
Secondary Aluminum:		10^3 kkg production			736	1,017	1,357	1,676^c		
Scrap Milling:	All	Percent of production	1973	8.0					346	1973
	Dry	Percent of production	1973	5.9					346	1973
	Wet	Percent of production	1973	2.1					346	1973

TABLE XV-3 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 333, 334

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Secondary Non-Ferrous Metals:	Production	10^3 kkg	1977	3,085					89	1972
Secondary Copper:	(From oil scrap only)	10^3 kkg	1970	457	404				350	1972
	Consumption		1972	907	850				83	1972
	Consumption		1973	984					83	1972
Secondary Zinc:	Production	10^3 kkg	1970	240	253				226	1973
Secondary Lead:	Production	10^3 kkg	1970	542	541				228	1972

---

[a] Approximately 50 percent by weight of Al_2O_3 is aluminum. Therefore the weight of Al_2O_3 was calculated by multiplying the weight of Al by 2.

[b] It is assumed that the trend from 1968 to 1971 to 1973 results in approximately 70, 20, and 10 percent of the 1975 aluminum being produced in prebaked, horizontal, and vertical steel Soderberg pots, respectively. Thereafter the percentages are assumed to remain constant.

[c] Assumed 22% of primary production based on trend established from restricted data from Ref. 350.

TABLE XV-4
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 333,334

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Primary aluminum		10^3 kkg Al_2O_3	7,120	127	9,350	127	12,330	127	15,240	127
Primary aluminum smelting	Horiz. stud Soderberg	10^3 kkg Al	797	343	925	b	1,233	b	1,524	b
	Vert. stud Soderberg		431	343	463	b	617	b	762	b
	Total Soderberg		1,228	343	1,388	b	1,850	b	2,286	b
	Prebaked		2,332	343	3,238	b	4,318	b	5,333	b
Bauxite refining	Surinam ore	10^3 kkg Al_2O_3	1,420	a	1,870	a	2,480	a	3,060	a
	Jamaica ore		4,560	a	6,000	a	7,900	a	9,800	a
	Arkansas ore		1,110	a	1,470	a	1,950	a	2,410	a
Primary copper	Production	10^3 kkg	1,443		1,688		2,032		2,422	
	Roasting	Percent of prod.	40	c	40	c	40	c	40	c
		10^3 kkg	580	c	680	c	810	c	970	
Primary zinc	Production	10^3 kkg	769	226	896	229	983	220	1,001	d
Primary lead	Production	10^3 kkg	590	228	612	228	645	228	678	228
Secondary aluminum	Scrap milling–all	10^3 kkg	58.9		81.4		108.6		134	

TABLE XV-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 333,334

Item	Process or Activity	Physical Units (Metric)	1971 Quantity	1971 Ref. No.	1975 Quantity	1975 Ref. No.	1980 Quantity	1980 Ref. No.	1985 Quantity	1985 Ref. No.
Secondary Aluminum	(Cont.)									
	Scrap milling-dry		43.4	e	601	e	87.3	e	113	e
	Scrap milling-wet		15.5	f	21.3	f	21.3	f	21.3	f
Metal cooling		10^3 kkg	736	g	1,017	g	1,357	c	1,676	g
	Contact wet		618	h	711	h	678		848	h
	Air (& contact evaporation)		118	h	306	h	679	d	838	h
Secondary zinc	Production	10^3 kkg	253	226	282	i	304	i	341	i
Secondary aluminum -scrap milling	Total prod.	10^3 kkg	737	351	1,019	i	1,357	j	1,676	j
	Dry		43.4	e	60.1	e	87.3	e	113	e
	Wet		15.5	f	21.3	f	21.3	f	21.3	f
	Total		58.9		81.4		108.6		134	
Secondary copper	Production	10^3 kkg	404	350	578	k	697	k	830	k
Secondary lead	Production	10^3 kkg	541	228	661	l	696	l	731	l
Total secondary nonferrous metals			1,934		2,538		3,054		3,577	

TABLE XV-4 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 333, 334

[a] Based on percentage breakdown of ore types from Table XV-3.

[b] See footnote (b) to Table XV-3.

[c] Assumed to remain at percentage cited in Ref. 10.

[d] Extrapolated from 1971 to 1985 trend.

[e] It is assumed that wet scrap milling will not increase after 1975 and that dry milling will increase and account for all of the extra milling. This is derived from an analysis of the discussion in Ref. 346.

[f] Estimated to be 0.22 percent of consumption from data in Table XV-3.

[g] These are the total amounts of aluminum smelted.

[h] Due to its advantages (346), it is estimated that contact evaporation will be used in 50 percent of products by 1985. This figure was estimated by the qualitative evaluation in Ref. 346.

[i] Estimated equal to 0.218 percent of consumption.

[j] Estimated equal to 0.22 percent of primary production.

[k] Esimated equal to 0.34 percent of primary production.

[l] Estimated equal to 1.1 percent of primary production.

TABLE XV-5
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 333, 334

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Particulates:						
Primary aluminum smelting	Horiz. stud Soderberg	169	58	64	86	107
	Vertic. stud Soderberg	169	17	19	25	30
	Total Soderberg	169	75	83	111	137
	Prebaked anode	169	64	89	119	146
Primary lead		89	248	257	271	285
Primary zinc		89	666	776	851	867
Primary copper		169	312	365	439	523
Total primary nonferrous			1,365	1,570	1,791	1,958
Secondary nonferrous:						
Smelting & refining		89	57	75	90	105
Total primary and secondary			1,422	1,645	1,881	2,063

TABLE XV-5 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 333, 334

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
SO_x :						
Primary copper	Roasting	169	70	82	97	116
	Smelting/ converting	169	3,434	4,018	4,836	5,764
Total primary copper			3,503	4,100	4,933	5,880
Primary lead		169	389	404	426	447
Primary zinc		169	846	986	1,081	1,101
Total primary			4,738	5,490	6,440	7,428
Suspended Solids:						
Bauxite refining	Surinam ore	347	468	616	317	1,010
	Jamaica ore	347	4,560	6,000	7,900	9,800
	Arkansas ore	347	2,220	2,940	3,900	4,820
Total bauxite refining			7,248	9,556	12,617	15,630

TABLE XV-5 (Cont.)

DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE

SIC 333, 334

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Suspended Solids (Cont.)						
Secondary						
Aluminum						
Scrap milling	Wet	346	11.1	15.4	15.4	15.4
Metal cooling	Contact	346	0.4	0.5	0.5	0.6

and become suspended solids. The confidence level for discharge estimates is 3, indicating a possible 25 percent variation in the data.

Likely Pollution Treatment Processes.

Figures XV-3 and XV-4 illustrate the treatment processes used for air and water pollutants, respectively, in the smelting and refining of primary and secondary nonferrous metals. Table XV-6 lists likely pollution treatments for other industries.

Air Pollution Control. The method of abatement of particulate and hydrogen fluoride emissions from primary aluminum smelting is fluidized-bed dry scrubbing using alumina feed.[345] This method is applicable in prebaked anode pots and vertical stud Soderberg pots.[345] If wet scrubbers are used, the suspended solids and fluorides are precipitated with lime or sodium aluminate (1977 effluent limitation), and a bleed stream is further treated with lime and the water is recirculated (1983 effluent limitations). Where sodium aluminate is used, the cryolite precipitated is recycled into the pot.

The SO_X emitted by primary copper, lead, and zinc plants is either cycled through sulfuric acid recovery plants or captured as $CaSO_4$ by lime scrubbers. Particulates from these metals are controlled by the same methods.[89]

Air pollutants from secondary aluminum are controlled by baghouses or specially treated fabric filters. Secondary copper, zinc, and lead particulate controls are achieved by baghouses and/or by wet scrubbers. Ponding is the only available water pollution control method for the mud from bauxite refining.

Water Pollution Control. Water pollution from secondary aluminum production is controlled by either settling and evaporating wet milling effluents or changing from wet to dry milling.[345] Wet scrubber effluents resulting from chlorination are neutralized and settled (1977). Chlorination effluents may be reduced by substituting ozonation (1983) or other methods (1983), such as Alcoa and Derham lime control processes, which use little or no water. A change from water cooling of new aluminum to air cooling, or continuous recycling of cooling water with precipitation of suspended solids and sludge disposal could also be used. Table XV-6 presents the efficiencies, costs, and residue ratios of the treatments discussed above.

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Most residues produced by treatment processes are either too impure for reuse or are produced in quantities too large to be marketable. Important exceptions to this are cryolite from cryolite precipitation and alumina from fluid-bed dry scrubbing of particulates in the primary aluminum industry. Table XV-7 lists estimated reuse levels of various residues. The reuse data have a confidence level of 2, indicating a possible 50 percent variation.

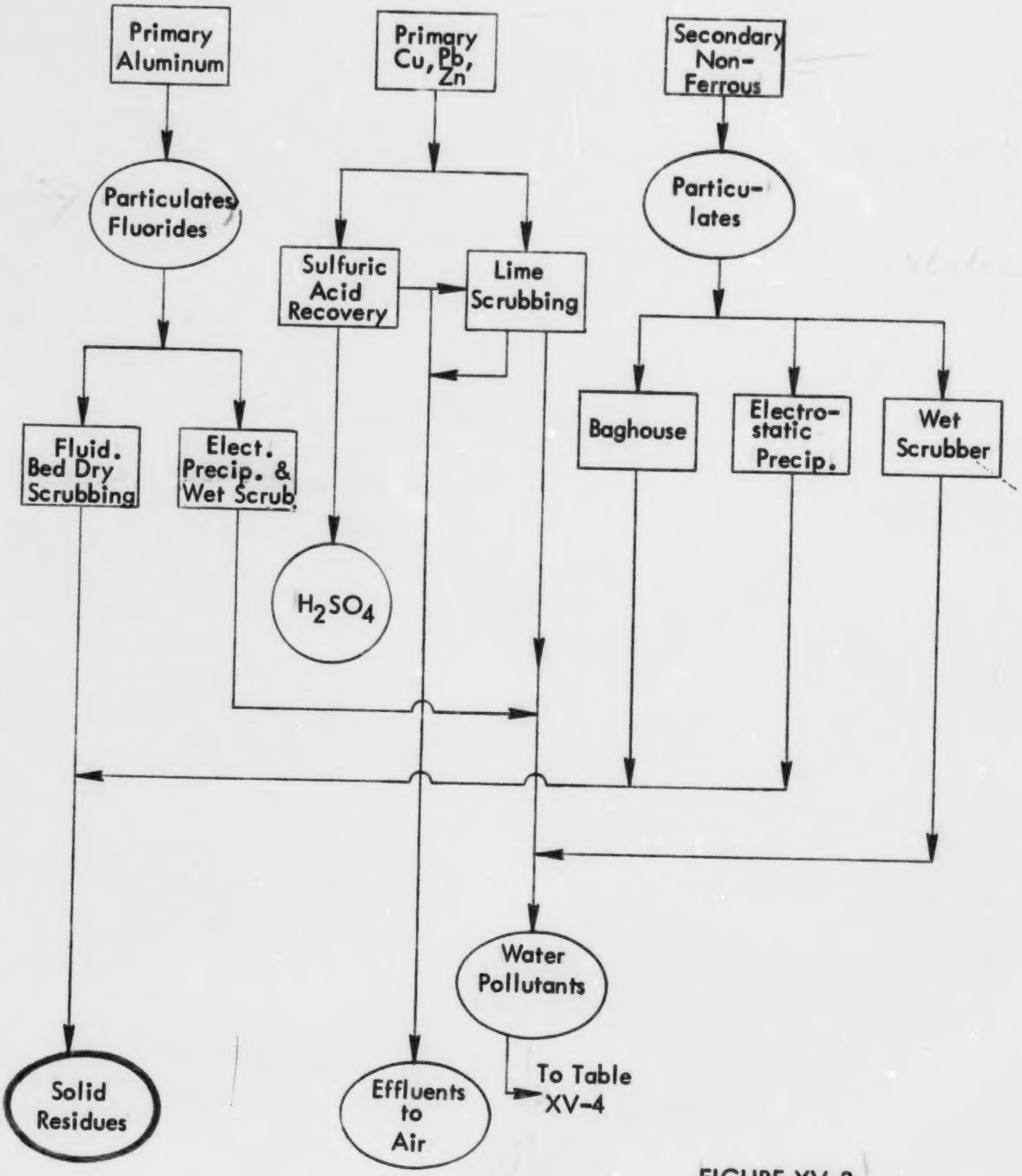
Primary Aluminum
Primary Cu, Pb, Zn
Secondary Non-Ferrous
Particulates Fluorides
Sulfuric Acid Recovery
Lime Scrubbing
Particu-lates
Fluid. Bed Dry Scrubbing
Elect. Precip. & Wet Scrub
Baghouse
Electro-static Precip.
Wet Scrubber
H_2SO_4
Water Pollutants
To Table XV-4
Solid Residues
Effluents to Air

FIGURE XV-3
AIR POLLUTION TREATMENT
PROCESS SCHEMATIC:
PRIMARY AND SECONDARY
NONFERROUS SMELTING AND
REFINING

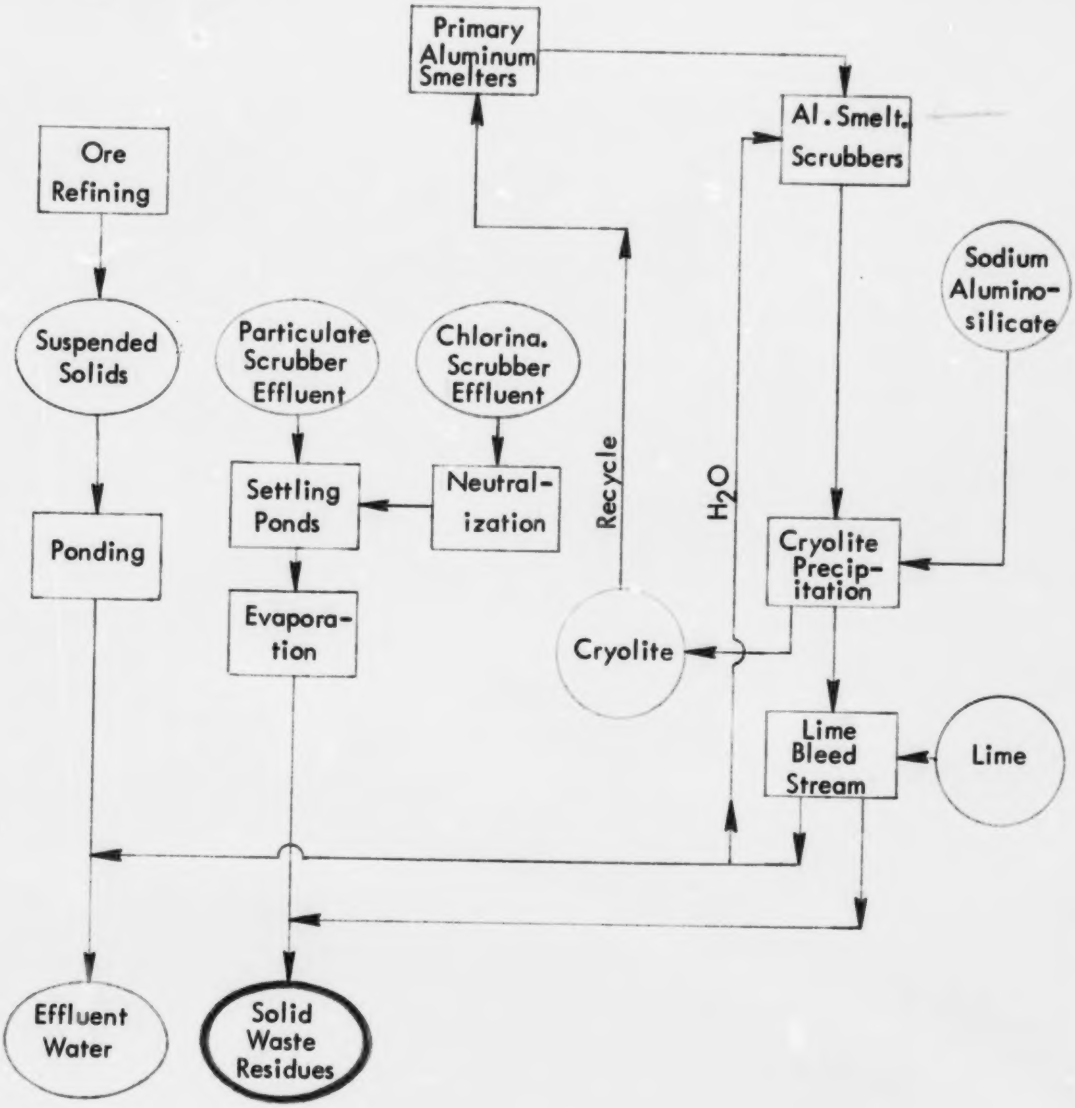
Primary Aluminum Smelters
Al. Smelt. Scrubbers
Ore Refining
Sodium Alumino-silicate
Suspended Solids
Particulate Scrubber Effluent
Chlorina. Scrubber Effluent
Recycle
H_2O
Settling Ponds
Neutral-ization
Ponding
Cryolite Precip-itation
Evapora-tion
Cryolite
Lime Bleed Stream
Lime
Effluent Water
Solid Waste Residues

FIGURE XV-4
WATER POLLUTION TREATMENT
PROCESS SCHEMATIC:
PRIMARY AND SECONDARY
NONFERROUS SMELTING AND
REFINING

TABLE XV-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 333, 334

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
AIR POLLUTANTS							
Primary aluminum Smelting	Prebaked	Particulates, fluorides	Fluidized-bed dry scrubbing	97.1-98.2	1	13.05/kkg Al	89,344
		Particulates, fluorides	Electrostatic precip.	(94.5-97.2) 96 (80-88) 84	1		
	Horiz. stud. Soderberg	Particulates, fluorides	Wet scrubber	(80-88) 84	n.d.	41	89,344
			Electrostatic precip.	97.2	1		
			Wet scrubber	84	n.d.		
	Vertical stud. Soderberg	Particulates, fluorides	Electrostatic precip.	94.5	1	41	89,344
			Wet scrubber	84	n.d.		
	Overall	Particulates, fluorides--	Ave. elect. prec.	96	1		
			Wet scrubber	84	n.d.		
Secondary nonferrous	All	Particulates	Miscellaneous	95	1	2.56	89
Primary copper, lead and zinc		SO_X	Sulfuric acid recovery	86	0		3

TABLE XV-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 333, 334

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Primary copper, lead and zinc (Cont.)		SO_x	Sulfuric acid recovery plus lime scrubbing	90	1.5[a]		169
			Lime scrubbing	90	2.2[b]		158
		Particulates	Overall	56-62	1		89
WATER POLLUTANTS							
Primary aluminum smelting	Wet scrubbers	Suspended solids	Cryolite precipitation plus water recycle	96	2		343[c]
			Cryolite precipitation plus lime bleed stream	100	2		343[c]
			Lime, once through	(50-80) 65	1		343
			Lime & recycle	96	1		343
			Lime & recycle plus lime bleed stream	100	1		343

TABLE XV-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
CAPABLE OF GENERATING SOLID WASTE
SIC 333, 334

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Secondary aluminum scrap milling	Wet	SS	Settle	99.9+	1	12-26.2	346
			Settle and evaporate, low flow	100	1	40	346
Secondary aluminum metal cooling	Contact	TDS, SS	Precipitation, recycling of water	100	1	0.5-0.9	346
Bauxite refining	Surinam ore	Settled mud	Ponding	100	1	Capital $0.08-0.17 \times 10^{-3}$ Operating $0.30-0.40 \times 10^{-3}$	342 342
	Jamaica ore	Settled mud	Ponding	100	1	Capital 0.20×10^{-3} Operating 0.50×10^{-3}	342 342
	Arkansas ore	Settled mud	Ponding	100	1	Capital $0.20-0.40 \times 10^{-3}$ Operating $0.20-0.50 \times 10^{-3}$	342 342

TABLE XV-6 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
CAPABLE OF GENERATING SOLID WASTE
SIC 333, 334

[a] Based on ratio of weight of H_2SO_4 to SO_2.

[b] See derviation in Section XVI in Power Plants.

[c] Cryolite is 30 percent of the suspended solids that settle out from cryolite scrubbing.[343] Since fluorine emissions amount to about 15 kg/kkg of aluminum;[345] and fluorine is 70 percent of creolete;[343] then

$$\frac{\text{1 kg Cryolite}}{\text{.7 kg Fluorine}} \times \frac{\text{15 kg Fluorine}}{\text{kkg Al}} \times \frac{\text{1 kg SS}}{\text{.3 kg Cryolite}} = \frac{\text{71 kg SS}}{\text{kkg Al}}$$

and thus:

$$\frac{\text{71 kg SS}}{\text{kkg Al}} \times \frac{\text{1 kg Cal}}{\text{15 kg Fluorine}} \times \frac{\text{1 kg Flourine}}{\text{3.3 kg Chloride}} = \frac{\text{71 kg SS}}{\text{40 kg}}$$

$$= \frac{\text{2 kg Residue (SS)}}{\text{kg Fluorides}}$$

TABLE XV-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 333,334

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Particulates	Primary aluminum -prebaked anode	Fluidized bed dry scrubber plus filter bag	100	344	AlF_2, Al_2,O_3
	-all	Scrubber	0-30	343	
	Primary copper, lead, zinc	SO_X scrubbing	0	89	$CaSO_4$ and $CaCO_3$
	Secondary aluminum dry scrap milling	Baghouse	0	346	Dust, organic and inorganic components, Al_2 O_3
	Secondary nonferrous metals	All	70	89, 169, 346	Soot, metal oxides, metals, fuming fluxes
Settled mud	Bauxite refining	Ponding	0	342	Settled "mud": oxides and hydroxides of Al, Fe, Si, Ti, Ca, and other metals
Suspended solids	Primary aluminum smelting	Scrubber effluent lime & settle, with or without recycle	0	343	CaF_2, Al compounds[a], hydrocarbons, carbon[a]
		Scrubber effluent cryolite precipitation	30	343	Cryolite (30%), carbon[a] (10%), Al compounds and other metal hydroxides (60%)
		Scrubber effluent lime precipitation	0	343	Al and other metal hydroxides

TABLE XV-7 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 333, 334

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref No.	Description/Disposal of Residue
Suspended solids (Cont.)	Secondary aluminum wet scrap milling	Settle	0	346	Dirt, mixed inorganic, organic
		Settle and evaporate	0	346	Fluxing salts, impurities
	Secondary nonferrous smelting	All	0		Wet particulates (soot, metal oxides, metals, fuming fluxes)

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[a] Negligible in prebaked.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables XV-8 to 11 list forecasts of solid waste residues from pollution treatment processes in primary and secondary nonferrous smelting and refining for 1971, 1975, 1980 and 1985, respectively. Total solid waste residues from air and water pollution controls are forecast to increase from 5,990 million kilograms in 1971 to 27,520 million kilograms in 1985.

The largest amounts of solid residues are generated in bauxite refining and in lime scrubbing of SO_X produced in primary copper, lead, and zinc manufacture. The amount of solid wastes generated by all of the other contributing processes is much smaller .

In Tables XV-8 through XV-11 the proportion of SO_X that goes into acid recovery plants was estimated from the fact that one-third of primary lead smelters and 60 percent of primary zinc smelters have acid recovery plants.[3] In the case of copper, a figure of 23 percent was chosen so that the 1971 19 percent control[89] would be achieved assuming an 86 percent SO_X removal by acid recovery plants.[3]

The confidence level in the final forecasts is 2, indicating a possible variation of about 50 percent in the data.

Composition of Solid Waste Residues from Pollution Treatment Processes.

Two main types of solid wastes can be distinguished in the industries under consideration. The solid waste from air pollution treatment is predominantly due to SO_X treatment and removal in primary metal processing. Except for higher trace amounts of heavy metals, general characteristics of the residue are the same as that described in the following Section on power plants, Section XVI.

The composition of the settled mud, the second main type of residue, depends on water content, ranging from 20 percent to over 60 percent solids,[342] depending on the amount of drying. The average solid content has been chosen to be 50 percent.[342] Over 95.5 percent of the solids pass through a 325-screen mesh;[342] this means the solids are clays or potential suspended solids. The oxides of five metals account for 45 percent of the weight of the solids: Al, Si, Ti, Ca, and Na.[342] Fe_2O_3 accounts for about half of the weight.[342] About 1.5 percent of the weight is due to oxides of Mg, K, Cr, Zn, Zr, Ni, V, Sr, and others.[342] Although the settled mud has possible potential use in the manufacture of cement or bricks, or as an iron ore source, no practical, economic use has yet been developed.[342] Table XV-12 presents the chemical composition of solid waste residues from primary and secondary nonferrous metals smelting and refining.

TABLE XV-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 333, 334

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Primary aluminum smelting	Prebaked	Dry collection	20	15	80	10	0	0
		Wet scrubbing	80	(50)	80	(40)	To SS water treatment	
	Soderberg (total)	Wet scrubbing	100	(80)	80	(60)	To SS water treatment	
		Total		(140)	78	(110)	91	(100)
Primary lead, zinc and copper		Dry collection	100[a]	1,230	56[a]	690	100	690
		Total primary		(1,370)	58	(800)	99	(790)
Smelting and refining of secondary nonferrous metals		Fabric filter	53[b]	30	95	30	30	10
		Wet scrubber	17[b]	(10)	95	(10)[c]	To SS water treatment	
		None	30[b]	0	-	0	0	0
		Total	100	(40)	100	(40)	50	(20)
Total Residues from Particulate Air Pollution Control:				1,280	n.a.	730	n.a.	700

TABLE XV-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 333,334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
SO_X:								
Primary lead	All	Sulfuric acid recovery	33[d]	130	86	110	0	0
		None	67	0				0
		Total	100	130				0
Primary zinc	All	Sulfuric acid recovery	60[d]	510	86	440	0	0
		None	40	0		0	0	0
		Total	100	510				0
Primary copper	All	Sulfuric acid recovery	23[d]	810	86	690	0	0
		None	77	0	0	0		0
		Total SO_X		1,450	86	1,240	0	0
Total Residues from Air Pollution Control:				2,730	n.a.	1,970	n.a.	700

TABLE XV-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Settled Mud:								
Bauxite refining	Surinam ore	Ponding	100	470	100	470	100	470
	Jamaica ore	Ponding	54.6	2,490	100	2,490	100	2,490
		None	45.4			0		0
	Arkansas ore	Ponding	100	2,220	100	2,220	100	2,220
		Total		5,180	100	5,180	100	5,180
Suspended Solids:								
Primary aluminum smelting								
		None	8				0	0
		Cryolite precip. & water recycle	18	40		40	70	25
		Cryolite precip. & lime bleed stream	0		100	0	76	0
		Lime, once through	9	10	65	6	100	6
		Lime recycle	21	25	96	20	100	20
		Lime recycle plus bleedstream	44	50	100	50	100	50
		Total	100	120	100	120	83	100

TABLE XV-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended Solids: (Cont.)								
Secondary aluminum								
-scrap milling	Wet	Settling	100	10	100	10	100	10
-metal cooling	Contact	Precipitation plus water recycle	19	0.08	100	negl.	100	negl.
		None	81	—		0		0
		Total		10		10		10
	Wastewater treatment	Settling & precipitation	50	5	70^e	4	100	4
		None	50				0	0
Total Residues from Water Pollution Control:				5,320	100	5,310	100	5,290
Total Residues from Air and Water Pollution Control:				8,050	90	7,280	82	5,990

TABLE XV-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC 333, 334

[a] The total net controls are 56 and 62 percent (in 1980 and thereafter). It is assumed that 100 percent is treated at 56 (and 62 in 1980) percent efficiences.

[b] It is assumed that all of the controls are fabric filters, except for 45 percent of the aluminum production, which is 38 percent of the total nonferrous metal production. Hence, 17 percent is wet scrubbed. The 30 percent untreated is the figure that will result in a 66 percent overall control.[89] The rest is assigned to fabric filters. Future wastewater guidelines[346] will result in keeping the output of air pollutants treated by wet scrubbers constant: new plant capacity will be equipped with fabric filters.

[c] Residues created during scrubbing and transferred to water as suspended solids where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid wastes explains the water pollutant estimates, since no solid wastes are created until treatment occurs following intermedial transfer.

[d] Assuming that for SO_X recovery, the percentage of smelters having acid recovery plants are:

- primary lead 33%
- primary zinc 60%
- primary copper 23% (23% control at 85% efficiency in order to reach the required 19% control.)

[e] The efficiences of wastewater treatment have been assumed to be those in secondary aluminum.[346]

TABLE XV-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Primary aluminum smelting	Prebaked	Dry collection	60	50	99	50	0	0
		Wet scrubbing	40	(40)	96	(30)	To wastewater treament	
		Total	100					
	Soderberg	Wet scrubbing	100	(80)		(80)	To wastewater treatment	
		Total		(170)	94	(160)	69	(110)
Primary lead, zinc and copper		Dry collection	100[a]	1,400	56[a]	780	30	240
		Total primary		(1,570)	60	(940)	37	(350)
Smelting & refining of secondary nonferrous metals		Fabric filter	68[b]	50	95	50	30	10
		Wet scrubber	17[b]	(10)	95	(10)[c]	To wastewater treatment	
		None	15[b]	—		0	0	0
		Total	100	(60)	100	(60)	33	(20)
Total Residues from Particulate Air Pollution Control:				1,500	n.a.	880	n.a.	250

TABLE XV-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
SO_X:								
Primary lead	All	Sulfuric acid recovery	33[d]	130	86	110	0	0
		None	67				0	0
		Total	100					
Primary zinc	All	Sulfuric acid recovery	60[d]	590	86	510	0	0
		None	40				0	0
		Total	100					
Primary copper	All	Sulfuric acid recovery	23[d]	940	86	810	0	0
		None	77	—	n.a.	—	0	0
		Total	100	940		810		
		Total SO_X		1,660	86	1,430	0	0
Total Residues from Air Pollution Control:				3,160	n.a.	2,310	n.a.	250

TABLE XV-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Settled Mud:								
Bauxite refining	Surinam ore	Ponding	100	620	100	620	100	620
	Jamaica ore	Ponding	100	6,000	100	6,000	100	6,000
	Arkansas ore	Ponding	100	2,940	100	2,940	100	2,940
		Total		9,560	100	9,560	100	9,360
Suspended Solids:								
Primary aluminum smelting								
		Cryolite precip. & water recycle	10	25	96	25	70	15
		Cryolite precip. & lime bleed stream	10	25	100	25		15
		Lime, once through		-	-		-	
		Lime recycle	36	45	96	40	100	40
		Lime recycle plus lime bleed stream	44	50	100	50	100	50
		Total		140	100	140	86	120

TABLE XV-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 333, 334

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended Solids: (Cont.)								
Secondary aluminum								
-scrap milling	Wet	Settling	100	15	100	15	100	15
-metal cooling	Contact	Precipitation & water recycle	19	0.1	100	negl.	100	negl.
		None	81	0		—	0	0
		Total		15	100	15	100	15
	Wastewater treatment	Settling & precipitation	75	8	100	8	70^e	6
		None	25	-	n.a.		0	0
Total Residues from Water Pollution Control:				9,720	100	9,720	100	9,700
Total Residues from Air and Water Pollution Control:				12,880	93	12,030	83	9,950

TABLE XV-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 333, 334

[a] See Table XV-8.

[b] See Table XV-8.

[c] See Table XV-8

[d] See Table XV-8.

[e] See Table XV-8.

TABLE XV-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6: Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6: Net Solid Residues	% Not Reused	Weight in Kg x 10^6: Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Primary aluminum smelting	Prebaked	Dry collection	100	120	99	120	0	0
	Soderberg	Wet scrubbing	100	(110)	96	(110)	To wastewater treatment	
		Total		(230)	98	(230)	48	(110)
Primary lead, zinc & copper		Dry collection	100[a]	1,560	62[a]	970	100	970
		Total primary		1,790	67	1,200	100	1,200
Smelting & refining of secondary non-ferrous metals		Fabric filter	85.5[b]	80	95	70	100	70
		Wet scrubber	14.5[b]	(10)	95	(10)[c]	To wastewater treatment	
		Total	100	(90)	89	(80)	100	(80)
Total Particulates from Particulate Air Pollution Control:				1,760	n.a.	1,160	n.a.	1,040

TABLE XV-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
SO_X:								
Primary lead	All	Sulfuric acid recovery & lime scrubbing	33[d]	210	90	190	6	10
		Lime scrubbing	67	630	90	560	100	560
		Total	100	840	89	750	76	570
Primary zinc	All	Sulfuric acid recovery & lime scrubbing	60[d]	970	90	880	6	50
		Lime scrubbing	40	950	90	860	100	860
		Total	100	1,920	91	1,740	52	910
Primary copper	All	Sulfuric acid recovery plus lime scrubbing	23[d]	1,700	90	1,530	6	90
		Lime scrubbing	77	8,369	90	7,520	100	7,520
		Total	100	10,060	90	9,050	84	7,610
		Total SO_X		12,820	90	11,540	79	9,090
Total Residues from Air Pollution Control:				14,580	n.a.	12,700	n.a.	10,130

TABLE XV-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Settled Mud:								
Bauxite refining	Surinam ore	Ponding	100	820	100	820	100	820
	Jamaica ore	Ponding	100	7,900	100	7,900	100	7,900
	Arkansas ore	Ponding	100	3,900	100	3,900	100	3,900
		Total		12,620	100	12,620	100	12,620
Suspended Solids:								
Primary aluminum smelting								
		Cryolite precip. & water recycle	20	50	96	45	70	30
		Lime recycle	32	40	96	35	100	35
		Lime recycle & lime bleed stream	48	60	100	60	100	60
		Total	100	150	93	140	86	120
Secondary aluminum								
-scrap milling	Wet	Settling	100	15	100	15	100	15
-metal cooling	Contact	Precipitation & water recycle	100	0.5	100	negl.	100	negl.
		Total		15	100	15	100	15

TABLE XV-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 333.334

				Weight in Kg × 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total Residues from Water Pollution Control:				12,800	100	12,780	100	12,770
Total Residues from Air and Water Pollution Control:				27,380	93	25,480	90	22,900

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[a] See Table XV-8.

[b] See Table XV-8.

[c] See Table XV-8.

[d] See Table XV-8.

[e] See Table XV-8.

TABLE XV-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Primary aluminum smelting	Prebaked	Dry collection	100	150	99	140	0	0
	Soderberg	Wet scrubbing	100	(140)	96	(130)	To wastewater treatment	
		Total		(290)	93	(270)	48	(130)
Primary lead, zinc & copper		Dry collection	100^a	1,680	62^a	1,040	100	1,040
		Total		1,970	66	1,310	100	1,310
Smelting & refining of secondary non-ferrous metals		Fabric filter	88^b	90	95	90	100	90
		Wet scrubber	12^b	(15)	95	$(10)^c$	To wastewater treatment	
		Total	100	109	92	100	90	90
Total Particulates from Particulate Air Pollution Control:				1,920	n.a.	1,270	n.a.	1,130

TABLE XV-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
SO_X:								
Primary lead	All	Sulfuric acid recovery & lime scrubbing	33[d]	220	90	200	6	10
		Lime scrubbing	67	660	90	590	100	590
		Total	100	880	90	790	76	600
Primary zinc	All	Sulfuric acid recovery & lime scrubbing	60[d]	990	90	890	6	50
		Lime scrubbing	40	970	90	870	100	870
		Total	100	1,960	90	1,760	52	920
Primary copper	All	Sulfuric acid recovery plus lime scrubbing	23[d]	2,030	90	1,830	6	110
		Lime scrubbing	77	9,960	90	8,960	100	8,960
		Total SO_X	100	14,830	90	13,340	79	10,590
Total Residues from Air Pollution Control:				16,750	87	14,610	80	11,720

TABLE XV-11(Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANTS								
Settled Mud:								
Bauxite refining	Surinam ore	Ponding	100	1,010	100	1,010	100	1,010
	Jamaica ore	Ponding	100	9,800	100	9,800	100	9,800
	Arkansas ore	Ponding	100	4,820	100	4,820	100	4,820
		Total		15,630	100	15,630	100	15,630
Suspended Solids:								
Primary aluminum smelting								
		Cryolite precip. & water recycle	20	60	100	60	70	40
		Lime, recycle plus lime bleed-stream	80	110	100	110	100	110
			—	—		—		—
		Total	100	170	100	170	88	150
Secondary Aluminum								
-scrap milling	Wet	Settling	100	15	100	15	100	15
-metal cooling	Contact	Precipitation & water recycle	100	0.6	100	negl.	100	negl.
			—	—		—		—
		Total		15	100	15	100	15

TABLE XV-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 333, 334

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Suspended Solids:	(Cont.)							
	Waste water treatment	Settling & precipitation	100	10	100[e]	10	100	10
Total Residues from Water Pollution Control:				15,820	100	15,820	100	15,800
Total Residues from Air and Water Pollution Control:				32,570	93	30,430	90	27,520

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[a] See Table XV-8.

[b] See Table XV-8.

[c] See Table XV-8.

[d] See Table XV-8.

[e] See Table XV-8.

TABLE XV-12

COMPOSITION OF SOLID WASTE RESIDUES FROM POLLUTION TREATMENT PROCESSES

SIC 333, 334

Item: Settled Mud

Process or Activity: Bauxite Refining

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	2	342
Volume	liters	1.26	342
H_2O content (of wet weight)	%	50	342
Combustible	kg	0	
Non-combustible	kg	2	
Ash content	kg	1.9	
Liquid form	kg	1	
Solid form	kg	1	342
Energy content	kcal	0	
Oxygen requirements	kg BOD_5	0	
Valuable metals	kg	0	
Volatile	kg	0	
Radioactivity	curies	0	
Radioactive material	kg	0	
Toxic chemicals	kg	0	
Pesticides & chem. warfare	kg	0	
Pathogens & bio. warfare	kg	0	
Explosives	kg	0	
Corrosives	kg	0	
Liquid hydrocarbons	kg	0	
Biodegradable	kg	0	
Non-biodegradable	kg	2	
Fe_2O_3 TiO_2	kg		
Al_2O_3 CaO	kg	1	342
SiO_2 Na_2O	kg		

Factors Affecting Quality of the Data.

There is sufficient available information concerning present discharge factors and economic trends to forecast quite accurate discharge inventories for the smelting and refining of nonferrous metals. The likely treatment processes are also known. It is more difficult to determine the reuse factors for solid waste residues. Reuse data is limited or not readily available. Much of the data used was obtained from a telephone survey of various plants. The uncertainty of the impact of new effluent limitations on the market for sulfuric acid leaves the future of the sulfuric acid recovery industry in doubt. Though settled mud from bauxite refining is believed to have potential use in the manufacturing of cement and bricks, it is not known to what degree this potential will be realized. The overall confidence level for the solid waste impact of pollution control in primary and secondary nonferrous metals' smelting and refining is 2, indicating a possible 50 percent variation in the data.

Summary.

Untreated Discharges. Nonferrous smelting and refining is a significant contributor to national discharges of air and water pollutants. Total particulate discharges before treatment are forecast to increase from 1,422 million kg in 1971 to 2,063 million kg in 1985. Over 95 percent of these emissions stem from primary smelting and refining. Sulfur oxide emission before treatment is forecast to increase from 4,738 million kg in 1971 to 7,428 million kg in 1985. These emissions are mostly from primary smelting and refining. Total suspended solids before treatment are also significant although reliable data exists only for bauxite refining. Bauxite refining discharges are forecast to increase from 7,248 million kg in 1971 to 15,630 million kg in 1985.

Treatment Processes and Reuse. Both mechanical and wet scrubbing methods are used to control particulate emissions from nonferrous smelting and refining. Fabric filters are becoming increasingly popular. Some plants currently control sulfur oxides by the use of sulfuric acid recovery plants. In the future lime scrubbers may be used on the recovery plant effluent gases in order to achieve the required level of control. Although the market is deteriorating, the sulfuric acid from the recovery plants is currently sold and probably will continue to be sold in the future. The increasing control of sulfur oxides may, however, reduce the market price considerably because of supplies glutting the market. Ponding and limestone precipitation are the current methods of controlling water pollutants. These methods create residues with little or no potential for reuse with the exception of cryolite precipitation (30 percent of the cryolete residues may be reused).

Residues Generated from Pollution Control: Types and Amounts. Total solid waste residues generated from air and water pollution control in nonferrous metals smelting and refining were forecast to increase from 5,990 million kg in 1971 to 27,520 million kg in 1985. These residues stem from both air and water pollution control. Lime scrubbing of SO_X emissions contributes the majority of air pollution control solid waste residues; settled mud from bauxite refining contributes most of the water pollution control solid waste residues. Calcium sulfates and sulfites are prevalent in the limestone scrubber residues. Metal oxides are prevalent in settled mud from bauxite refining. A landfill receiving solid waste residues from nonferrous smelting and refining could be expected to have relatively high metals content in its leachate.

SECTION XVI

ELECTRIC POWER PLANTS
SIC 491

Introduction

The Electrical Services Industry, SIC 491, produces and transmits electricity for public use. Additional electricity is also generated by some industries which operate their own on-site power plants. This on-site industrially-generated electricity is only a small proportion of the Nation's total electric power generation and is not included in SIC 491. For purposes of the analysis the latter will be included in this Section as part of the total electric power generated by coal, oil, and gas. No major nuclear or hydroelectric plants are currently operated on-site at industrial plants.

Steam power plants are the major nationwide source of the air and water pollution produced by the production and transmission of electricity. Lines and transmission equipment themselves are a very minor factor and will not be evaluated here. Hydroelectric power plants are also a relatively insignificant source.

Untreated Discharge Factors.

Air Pollutants. Coal, oil, and gas-fueled power plants dispose measurable quantities of six types of air pollutants: SO_x, NO_x, CO, CO_2, particulates, and hydrocarbons. Table XVI-1 lists the available rates for uncontrolled emissions of air pollutants from these fossil fuel power plants. Nitrous oxides, although in large quantities, are not yet controlled, presumably due to lack of cost-effective treatment methodology, and thus can be expected to have minimal impact on pollution control of the resultant solid waste. The major air pollutants that will impact on solid waste management are particulates and SO_x, both of which are generated in large amounts. The particulates contain large quantities of hydrocarbons; control of gaseous hydrocarbons generates minimal solid waste, and will not be further evaluated.

The discharge rates shown in Table XVI-1 are presented in terms of kg pollutant produced per kilowatt hour. Air pollutant discharge rates were converted to these units by the conversion factors footnoted in the table. The generation of one kwh of electricity was assumed to require 0.45 kg coal, 0.288 liters of fuel oil, or 0.3 cubic meters of natural gas. Air pollutant discharge factors for nuclear power plants are not presented in Table XVI-1, due to lack of available rate data per kwh. An inventory of radioactive wastes is presented in Table XVI-11.

Water Pollutants. Most water pollution in fossil-fuel power plants is caused by intermedial transfer of air pollutants to water during stack-gas scrubbing. Boiler water and gas scrubber water are both generally recycled within these plants. Water conditioning chemicals added to a 500 MW steam boiler running 12 hours a day are listed in Table XVI-2. The additives contribute dissolved solids which prevent scale build-up in the boiler tubes. Blowdown of water pollutants in terms of kg per kwh is presented

TABLE XVI-1
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 491

Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Bituminous coal comb., pulverized	General	kkg coal	Particulates	8 A[b]	169
	Wet bottom			6.5A	
	Dry bottom			8.5A	
	Cyclone			2A	
Fuel oil comb.		10^3 liters		1	
Natural gas comb.		10^6 m^3		240	
Bituminous coal comb., pulverized		kkg coal	Sulfur oxide	19S[c]	169
Fuel oil comb.		10^3 liters	Sulfur dioxide	19 S	
			Sulfur trioxide	0.25 S[c]	
Natural gas comb.		10^6 m^3	Sulfur oxides	9.6	
Bituminous coal comb., pulverized		kkg coal	Hydrocarbons	0.15	169
Fuel oil comb.		10^3 liters		0.25	
Natural gas comb.		10^6 m^3		640	
Bituminous coal comb., pulverized	General	kkg coal	Nitrogen oxides	9	169
	Wet bottom			15	
	Dry bottom			9	
	Cyclone			27.5	
Fuel oil comb.		10^3 liters		12.6	
Natural gas comb.		$10^6 m^3$		6,250	
Electric power generation	Coal	kwh	Particulates	0.044[d]	169
			SO_2	0.022[e]	
	Oil		Particulates	0.00029	
			SO_2	0.014[e]	
	Gas		Particulates	7.2×10^{-5}[f]	
			SO_2	2.9×10^{-6}[f]	

TABLE XVI-1 (Cont.)
SOURCES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 491

[a] For 1971 or most recent available information.

[b] A = ash content, percent.

[c] S = sulfur content, percent.

[d] Using 12 percent ash 2.5 percent sulfur coal, and 0.45 kg coal/kwh.

[e] Using 2.5 percent sulfur oil and 0.288 liters oil/kwh.

[f] Using 0.3 m^3 gas/kwh.

TABLE XVI-2
FOSSIL FUEL POWER PLANT WATER POLLUTION: SOURCES AND QUANTITIES OF CHEMICAL WASTES[22]

Process	Waste – Type and Quantity (kg)	Total Water, liters/ 500 MW plant
Lime softener	2,250/day Calcium and Magnesium carbonates	109,765
Filters	27.3/day Calcium and Magnesium carbonates	45,700
Circulating water[a]	40.9/day Free chlorine	204,000,000
Makeup demineralizer	211.4/day Sulfuric acid	36,714
	281.8/day Caustic soda	51,097
Condensate polisher	331.8/day Sulfuric acid	29,523
	177.3/day Caustic soda	12,869
Preoperational cleaning[b]		
Alkaline cycle wash	568.2 Disodium phosphate 1136.4 Trisodium phosphate	567,750
Alkaline boiler wash	227.3 Disodium phosphate 454.5 Trisodium phosphate	227,100
Acid cycle cleaning	11,303.6 Hydroxyacetic acid 5,681.8 Formic acid	567,750
Acid boiler cleaning (once through)	6,818.2 Hydroxyacetic acid 3,409.1 Formic acid	227,100
Acid boiler cleaning (conventional)	11,363.6 Hydrochloric acid	227,100

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[a] Circulating water = 1,006,810 lpm at 100 ppm alkalinity as $CaCO_3$.

[b] All on 100% basis.

in Table XVI-3. As effluent controls are enforced more strictly with time, these dissolved solids will be precipitated employing new waste treatment methods. The solid waste generated from boiler blowdown will probably be less than one percent of that generated through air pollution control. Wastes generated by boiler water feed are not considered in Table XVI-3; no economical methodology has been advanced for precipitating dissolved inorganic solids. Radioactive wastes are not listed in this discharge table due to lack of data in rate per kwh units, but will be discussed later in this Section.

The confidence level for uncontrolled air and water pollution discharge rate data is 3 for fossil-fuel plants, indicating a possible 25 percent variation in the data; nuclear emissions are not quantified.

Industry Description and Schematic.

Figures XVI-1 and XVI-2 contain schematics for fossil and nuclear fuel plants, respectively, including basic steps in the generation process with pollution controls. Air pollutants from fossil-fuel plants are discharged with furnace flue gases following combustion. Their fate may follow three paths: directly to the air (no controls); dry treatment (which directly creates solid residues); or wet treatment (which creates solid residues following water treatment).

Nuclear fission generators produce radioactive fission by-products in gaseous, liquid, and solid forms. Radioactivity is measured in curies (nuclear disintegrations per unit of time), while radioactive waste is measured in cubic meters or kilograms. Actually, these measures are not in themselves complete since some elements disintegrate rapidly (less than 20 minues) while others disintegrate slowly (100,000 years or more). Also some disintegrations (such as plutonium) release more powerful radiation than others.

Most radioactive wastes are low- or medium-level radioactive; these include processing by-products, used paper, contaminated drain water, and irradiated metal items. High-level radioactive wastes are generated in the reactor as gases leaking from the fuel capsules and in the reprocessing steps as liquids. Dangerous wastes contain by-products of fission: plutonium, strontium, and actinides.

Nuclear-fueled plants must retain spent fuel from six months to a year in order to allow fission by-products to disintegrate to a safer concentration. Reprocessing plants must keep the high-level wastes for 3-5 years in a liquid state before solidification and disposal. Fuel fabrication, the reactor, and fuel reprocessing are included in this Section. Uranium mining and milling are analyzed in Section V (Mining).

Economic Forecasts.

Nuclear fuel is predicted to be from as little as 28 to as much as 48 percent of total power generation by 1985. The growing problems connected with nuclear fission plants imply that the lower estimates may be more realistic. Public opinion, reactor control difficulties, control of radioactive wastes, control of thermal pollution, and the limited supply of U-235 limit the growth potential of nuclear power plants.

TABLE XVI-3
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
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Item	Process or Activity	Physical Units (Metric)	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Fossil fuel power plants		kwh	SS-ash	1.93×10^{-6}	170
			SS-other	56.75×10^{-6}	
			Non-degradable organics	7.59×10^{-6}	
			BOD_5	0.28×10^{-6}	
			Acid	9.39×10^{-6}	
			Alkalies	1.24×10^{-6}	
			Chlorine	3.04×10^{-6}	
			Phosphates	3.45×10^{-6}	
			Boron	28.3×10^{-6}	
			Chromates	9.28×10^{-6}	
			Total water	112.26×10^{-6}	

[a] For a 1,000 mw plant at 0.75 load factor, originally given in metric tons per year. Converted to kwh by $1{,}000 \times 10^3 \times 365$ days/year × 24 hrs/day × 0.75= kwh/year.

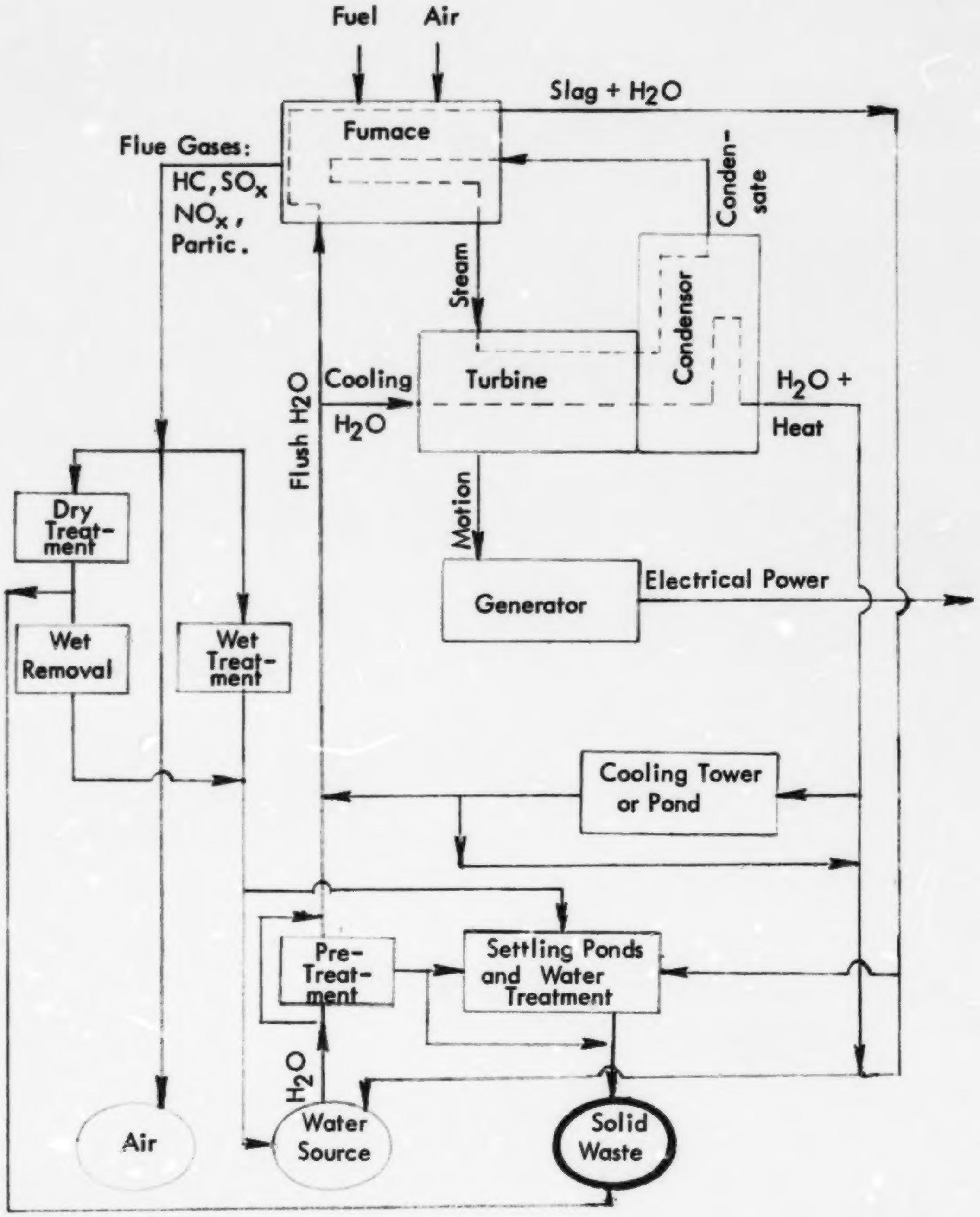
Fuel
Air
Slag + H_2O
Furnace
Flue Gases:
HC, SO_x
NO_x,
Partic.
Conden-sate
Steam
Condensor
Flush H_2O
Cooling
H_2O
Turbine
H_2O +
Heat
Motion
Dry Treat-ment
Generator
Electrical Power
Wet Removal
Wet Treat-ment
Cooling Tower or Pond
Pre-Treat-ment
Settling Ponds and Water Treatment
H_2O
Air
Water Source
Solid Waste

FIGURE XVI-1
INDUSTRY SCHEMATIC:
FOSSIL FUEL POWER PLANT

XVI-7

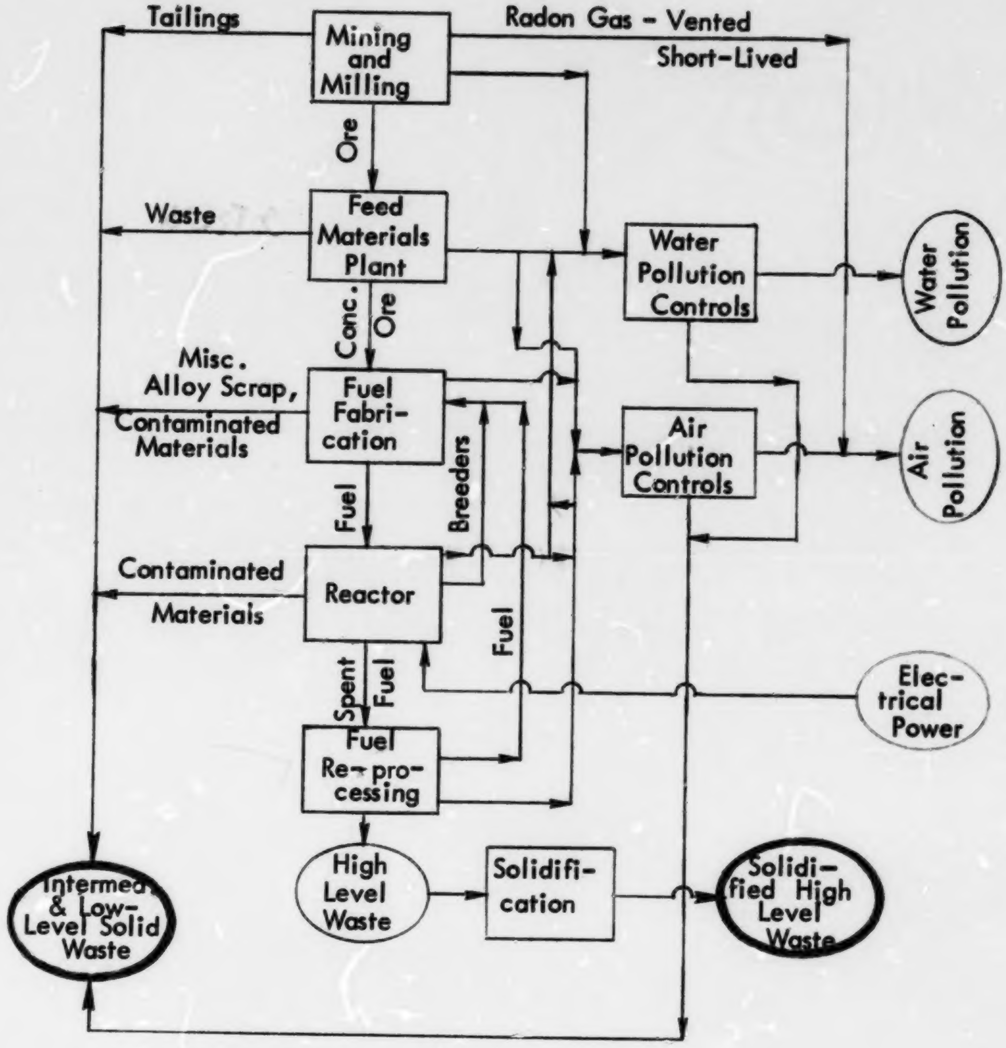
Tailings
Mining and Milling
Radon Gas - Vented
Short-Lived
Ore
Waste
Feed Materials Plant
Water Pollution Controls
Water Pollution
Conc. Ore
Misc. Alloy Scrap, Contaminated Materials
Fuel Fabrication
Air Pollution Controls
Air Pollution
Fuel
Breeders
Contaminated Materials
Reactor
Fuel
Spent Fuel
Electrical Power
Fuel Re-processing
High Level Waste
Solidification
Solidified High Level Waste
Intermed. & Low-Level Solid Waste

FIGURE XVI-2
INDUSTRY SCHEMATIC:
NUCLEAR POWER GENERATION

Coal is abundant, extractable at a relatively low cost, and generally acceptable as a power source. The construction of coal-fired power plants, such as Four Corners in Arizona, will continue as more coal fields are opened to large-scale mining operations. As shown in Table XVI-4, coal could supply all of the U.S. energy needs for the next 126 plus years at 1980 forecast energy levels. The use of coal power produces considerable quantities of air pollution.

The total demand for electricity over the last decade has been increasing six times as fast as the rate of population increase and twice as fast as real GNP.[170] Tables XVI-4 and XVI-5 summarize the sources and uses of electricity; Tables XVI-6 and XVI-7 summarize the National fuel reserves. Both the time and dollar cost of building more plants and the lessening amounts of available fuels are limits to production increases.

Table XVI-8 lists alternative available estimates of electric power growth through 1985. Estimates of nuclear power generation in 1985 range from one-quarter to one-half of total power generation.

Hydroelectric power will continue to be used, but future increases will probably be small. Oil and gas power production will become less feasible as reserves begin to grow scarce and expensive. The post-1985 future of the fuel industry is uncertain, but the future until 1985 is constrained by the limit of coal, oil and gas reserves, and nuclear fission technologies.

Table XVI-9 contains a comprehensive forecast of the sources of U.S. electricity supply through 1985, based upon the above data and discussions. The estimates seem generally consistent with the latest EPA projections; recent 1974 EPA study[433] estimated that 55 percent, 17 percent, and 28 percent of current fossil-fuel capacity is accounted for by coal, oil, and gas-powered plants, respectively. These percentages are similar to those of Table XVI-9 for 1971. The EPA study also estimated a 113 percent increase in coal-fired capacity from 1972 to 1985,[433] close to the 95 percent increase projected in Table XVI-9 for the coal-fired increase from 1971 through 1985.

The major area of uncertainty, both in the present study and in the 1974 EPA study, lies in the projection of nuclear power plant contributions to total power generation. On the whole, economic forecast data for electric power generation may be given a confidence level of 3, indicating a possible ± 25 percent variation.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

The control of three pollutants (particulates and SO_x from fossil-fuel plants, and radioactive wastes from nuclear plants) is likely to have a significant impact on solid waste. Carbon monoxide and hydrocarbons do not have an important impact; NO_x is forecast to be uncontrolled but will eventually be controlled by largely non-polluting methods such as stoichiometric oxygen levels, temperature reduction, and catalytic reduction. Table XVI-10 estimates the National discharge of these pollutants through 1985.

TABLE XVI-4

U.S. ENERGY CONSUMPTION, 1970 (PRELIMINARY) IN 10^{12} KCAL [114]

Source	Households and Commercial	Industry	Transportation[e]	Utilities	Misc.	Total[d]
Coal						
Anthracite	21.4	15.4	n.d.[f]	12.1		48.9
Bituminous and lignite	79.1	1,385.7	2.3	1,959.6		3,517.4
Dry, natural gas[a]	1,852.2	2,646.0	169.1	1,014.3		5,681.6
Petroleum[b]	1,599.9	1,277.4	3,970.5	570.3	45.4	7,463.5
Hydroelectric[c]				667.0		6,606.7
Nuclear power[c]				52.4		52.4
Total inputs	3,552.7	5,324.5	4,141.9	4,275.7	45.4	17,340.1
Electric utility purchases	713.8	573.3	4.5			1,309.6
Sector energy inputs	4,284.5	5,897.8	4,146.4		45.4	14,374.1

[a] Excludes natural gas liquids.

[b] Includes natural gas liquids.

[c] Hydro power and nuclear power converted to theoretical energy inputs from prevailing heat rates at central electric stations - 2,699.4 kcal/kwh.

[d] Includes energy from imported fuels.

[e] Includes bunkers and military transportation.

[f] No data available.

TABLE XVI-5
ENERGY USE BY MINERAL AND MANUFACTURING INDUSTRIES (1969) IN 10^{12} KCAL[114]

Source SIC:	Food (20)	Paper (26)	Chemicals (28)	Petroleum Refineries (29)	Stone, Clay and Glass (32)	Metals (33)	Mineral and Mfg. (Misc.)	Total
Coal								
Anthracite	0.7	1.6	1.6	n.d.	0.4	12.0	1.8	18.2
Bituminous and lignite	65.2	115.3	165.2	n.d.	101.2	697.9	242.6	1,387.3
Dry natural gas	161.6	92.9	332.2	275.8	122.3	235.2	1,302.8	2,522.7
Petroleum	38.5	60.6	409.6	456.3	25.0	87.4	207.1	1,284.9
Total gross	265.9	270.4	908.6	732.1	249.0	1,033.0	1,754.2	5,213.1
Utility, electricity purchases	58.9	27.9	164.5	22.4	79.9	128.7	156.6	559.2
Total sector inputs	324.8	298.3	1,073.1	754.5	328.8	1,161.2	1,910.8	5,772.3

TABLE XVI-6
USAGE RATES OF U.S. FOSSIL FUEL RESERVES[a]

	Coal (10^6 metric tons)	Oil (10^9 liters)	Natural Gas (10^{12} m^3)
Estimated reserves[51]	1,338,000	34,348	29.18
Present annual usage rate[107]	544	874	0.65
Usage: reserves	1:2,460	1:39	1:45

[a] Based on production as of 1971.

TABLE XVI-7

ESTIMATE OF AVAILABLE U. S. FUEL RESERVES FOR DOMESTIC ENERGY NEEDS

Fuel	Total Reserves	Requirement to supply total U. S. energy in 1980[a]	Ratio of requirements to reserves (percent)	Years future supply
Coal	1,331 x 109 metric tons	10.67×10^9 metric tons	0.79	126.5
Oil	34,348 x 109 liters	$6{,}765 \times 10^9$ liters	19.8	5.0
Gas	$29.18 \times 10^{12} m^3$	$7.05 \times 10^{12} m^3$	24.1	4.5
Uranium ore	598,802 metric tons	3,194 metric tons	0.53	170.0
Total years fuel will be available				306.0

[a] Approximately 20×10^{15} kcal will be required by 1980.

TABLE XVI-8
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 491

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Electric utilities	All	10^9 kwh	1970	539	1,614	2,194	3,086	4,263	400	1970
Industry electricals	All	10^9 kwh			104				400	1970
Electric power sources	Nuclear		1970	1.4	40				400	1970
	Coal				761					
	Oil				232					
	Gas				400					
	Hydroelectric				283					
	Nuclear/percent of utility capacity				2.4	10.8	22.0			

TABLE XVI-9
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC 491

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Total electric power[a]	Nuclear	10^9 kwh	40	400	237	170	679	170	1,280	170
	Coal		761		920		1,120		1,490	
	Oil		232		390		520		720	
	Gas		400		390		390		390	
	Hydroelectric		283		356		425		480	
	Total		1,716		2,293		3,134		4,360	

---

[a] Assumes a constant production of 100 x 10^9 kwh from industry generation throughout the forecast years.

TABLE XVI-10
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 491

Pollutant	Process or Activity	Ref. for Discharge Factor	Pollutant Discharge 1971	1975	1980	1985
Particulates (10^6 kg)	Coal	169	33,500	40,500	49,300	65,600
	Oil		70	110	150	210
	Gas		30	30	30	30
	Total		33,600	40,640	49,480	65,840
SO_2 (10^6 kg)	Coal	169	16,700	20,200	24,600	32,800
	Oil		3,200	5,500	7,300	10,100
	Gas		1	1	1	1
	Total		19,901	25,701	31,901	42,901
Radioactive gases[c] (kg)[a]		237				
	Milling		0.35×10^{-5}	2.1×10^{-5}	5.9×10^{-5}	11×10^{-5}
	Conversion		n.d.	n.d.	n.d.	n.d.
	Enrichment		0.41×10^2	3.4×10^2	6.8×10^2	13×10^2
	Fuel fabrication		0.27×10^2	1.6×10^2	4.5×10^2	8.5×10^2
	Irradiation		0.2×10^{-2}	1.2×10^{-2}	3.4×10^{-2}	6.4×10^{-2}
	Reprocessing		0.22×10^9	1.3×10^9	3.6×10^9	6.8×10^9
Radioactive liquids[c] (kg)[a]		237				
	Milling		0.11×10^9	0.6×10^9	1.8×10^9	3.4×10^9
	Conversion		0.27×10^9	1.6×10^9	4.5×10^9	8.5×10^9
	Enrichment		0.32×10^3	1.9×10^3	5.4×10^3	10×10^3
	Fuel fabrication		0.1×10^8	0.6×10^8	1.6×10^8	3.0×10^8
	Irradiation		0.49×10^{-2}	2.9×10^{-2}	8.2×10^{-2}	15×10^{-2}
	Reprocessing-low level		0.07×10^8	0.42×10^8	1.2×10^8	2.3×10^8
	-high level-7[b]		0.2 x 103	2.5 x 103	7.1 x 103	13 x 103

TABLE XVI-10 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 491

Pollutant	Process or Activity	Ref. for Discharge Factor	Pollutant Discharge			
			1971	1975	1980	1985
Radioactive solids[c] (kg)[a]		237				
	Milling		0.1×10^{10}	0.6×10^{10}	1.6×10^{10}	3.0×10^{10}
	Conversion		0.11×10^{4}	0.6×10^{4}	1.8×10^{4}	3.4×10^{4}
	Enrichment		n.d.	n.d.	n.d.	
	Fuel fabrication[b]		0.27×10^{2}	1.6×10^{2}	4.5×10^{2}	8.5×10^{2}
	Irradiation[b]		0.17×10^{4}	1.0×10^{4}	2.8×10^{4}	5.3×10^{4}
	Reprocessing[b]		0.43×10^{3}	2.5×10^{3}	7.1×10^{3}	13×10^{3}

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[a] For radioactive wastes, units are kg except where noted.

[b] Units: m^3.

[c] See Table XVI-11 for radioactive characteristics of the wastes.

The discharge inventories for sulfur oxides contained in Table XVI-10 assume an average sulfur content of 2.5 percent. This was the average sulfur percent of all fossil fuels burned in steam electric power generators in 1967.[89] Indications are that this percentage has been rising since 1967 due to demands from other consumers (metallurgical coal buyers and some small privately-owned power plants).[89] Recent finds of low-sulfur coals may offset this trend, although the current increase in coal usage due to the "energy crisis" and the oil import situation may tend to negate this increase in low-sulfur fuel availability. The recent EPA hearings on sulfur oxide control in power plants [433] concluded that only 73,000 megawatts, of a total coal-fired generating capacity of 209,000 megawatts projected for 1977, would require flue gas-cleaning devices. This amount was projected to increase to 90,000 megawatts by 1980.[433] It was further estimated that the other sources could achieve control by using available low-sulfur fuels. It is likely, however, that these 90,000 megawatts requiring controls would have a much higher average sulfur content than the 2.5 percent industry average, increasing somewhat the solid residue implications of controls. The same EPA study[433] estimated that a capacity of up to approximately 127,000 megawatts could require flue gas-cleaning devices (FGD) by 1980 if projected low-sulfur fuel supplies do not materialize.

Thus, the discharges before treatment of sulfur oxides may vary substantially as a function of the availability of low-sulfur fuels. The projections in this section could be as much as 50 percent higher if large amounts of low-sulfur coal are used for power generation.

Radioactive wastes were the most difficult pollutants to evaluate; these wastes are a small fraction of both total volume and weight of waste residues from power generation, but they can be the most toxic, depending on the specific isotopes involved. Table XVI-11 gives a more complete description of the wastes generated from nuclear power production.

TABLE XVI-11

RADIOACTIVITY LEVELS AND TYPES OF WASTES DISCHARGED BY NUCLEAR REACTORS[237]

Pollutant/Process	Total Annual Curies	Annual Curie Breakdown by Isotope	Type/Source of Waste
Radioactive gases			
Milling	9.0×10^3		Mostly Rn^{222}; particulate concentration unknown
Enrichment	5.3×10^{-1}		Leakage from process equipment escaping treatment
Fuel fab.	8.5×10^{-1}		Mostly particulate uranium
Irradiation	2.0×10^7		Stack discharge; most activity from noble gases
Reprocessing	2.7×10^7	Kr^{85}: 2.5×10^7 Ci: 1.6×10^6	Stack discharge
Radioactive liquids			
Milling	1.1		Effluent from tailing ponds
Conversion	7.0×10^{-1}		Off-gas scrubber solution to water; via limestone beds
Enrichment	4.1		Treated for release to water
Fuel fab.	2.0×10^1		Supernate from wastewater treatment
Irradiation	8.0×10^5	^3H: 8×10^5 Others: $\approx 10^3$	
Reprocessing (low)	3.0×10^4	^3H: 3×10^4 Others: 2×10^2	
Reprocessing (high)	6.6×10^9		Nitrate solution
Radioactive solids			
Milling	3.4×10^4	Ra^{226}:9×10^3 [a] Th^{230}:6×10^3 Pb^{210}:2×10^3 Pb^{210}:2×10^3	Mill tailings, abandoned piles stabilized against release; impounded solids from water treatment

TABLE XVI-11 (Cont.)
RADIOACTIVITY LEVELS AND TYPES OF WASTES DISCHARGED BY NUCLEAR REACTORS[237]

Pollutant/Process	Total Annual Curies	Annual Curie Breakdown by Isotope	Type/Source of Waste
Radioactive solids (Cont.)			
Conversion	5.3×10^1	U^{238}: 6×10^0 Ra^{226}: 1.6×10^0 Th^{230}: 4.6×10^1	Impounded solids from water treatment
Fuel fab.	1.3×10^6	Pu^{241}: 1.3×10^6 Pu^{240}: 4.8×10^3 Pu^{239}: 3.19×10^3 Pu^{238}: 1.9×10^4	Conglomerate solids, "solidified" liquid
Irradiation	2.2×10^7	Ag^{110}: 1.3×10^7 Fe^{55}: 8×10^6 Ag^{108}: 4×10^5 ^3H: 3.4×10^5 Mn^{54}: 2.5×10^5 Ni^{59}: 1.5×10^5	Control rods
Irradiation	1.0×10^6	^3H: 8×10^5 Fe^{55}: 4.5×10^4 Co^{60}: 1.7×10^4 Ru^{106}: 8×10^4 Cs^{134}: 1.1×10^4 Cs^{137}: 4.1×10^4	Conglomerate solids, "solidified" liquid
Reprocessing	1.3×10^8	Sr^{90}: 3.4×107[b] $Cs^{134-137}$: 6×10^7 Pn^{147}: 1.4×10^7	High level activity, cladding hulls, "solidified" liquids

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[a] Listed isotope radioactivities for mill tailings only.

[b] Listed isotope radioactivities for high level activities only.

The most highly radioactive wastes produced are high-level aqueous nitrates from reprocessing $(6.6 \times 10^9$ ci/year).[237]

Generally, the available discharge data are of better quality for fossil-fuel power plants than for nuclear reactor power plants. The fossil-fuel pollutant discharge data can be given a confidence level of 3, indicating a ± 25 percent possible variation, while the nuclear power discharge data can be given a confidence level of 2, indicating a larger ± 50 percent possible variation.

Likely Pollution Treatment Processes.

Table XVI-12 summarizes the air and water pollution treatment processes likely to be applied in electric power plants. Coal, oil, and gas produce essentially the same types of pollutants, differing mainly in rates. While coal is a relatively dirty fuel and requires air pollution control, gas does not require controls because it produces relatively few emissions. Combustion of even small quantities of coal usually requires immediate control for particulates and SO_x; control of emissions from oil burning requires less costly implementation; and gas burning requires still less control.

Nuclear plants require extensive controls but control problems (especially as opposed to disposal problems) are minimal. Collection is the common method of controlling liquid and solid wastes. Methods of controlling radioactive gaseous media are presently available; pilot methods are under study to convert liquid into solid media. Table XVI-13 describes generation of low and intermediate solid waste from nuclear reaction pollution control treatments; Table XVI-14 describes generation of high-level solidified solid waste from reprocessing plants.

Air Pollution Control. In addition to the use of low-sulfur fuels, at least three throw-away flue gas cleaning systems and three saleable product flue gas cleaning systems exist for sulfur oxide control. Small plants, and especially industrial plants, often rely on low-sulfur fuels, such as natural gas and imported oil, because of the fairly large capital costs of flue gas cleaning devices. The three main throw-away systems are: (1) lime scrubbing, (2) limestone scrubbing, and (3) furnace injection processes. The three main saleable product systems are: (1) magnesium oxide scrubbing, (2) Wellman-Lord (sodium sulfite scrubbing), and (3) catalytic oxidation.

The wet limestone and wet lime scrubbing systems are currently the most common throw-away systems, and to date have predominated over the saleable product systems. Dolomite injections into the furnace with or without subsequent slurry scrubbing have found less application. Although some potential reuse exists for the sludges produced by lime and limestone scrubbing processes (such as for walls, dams, road construction, etc.), most residues from planned or existing systems will probably be discarded. Wet limestone scrubbing, a schematic of which is presented in Figure XVI-3, basically operates at a near-stoichimetric rate. The reaction chain is shown in Equations XVI-1 and XVI-2 below:

TABLE XVI-12

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 491

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Coal combustion	Cyclone furnace	Particulates	Electrost. precipitator	65-99	1		169
			High-eff. cyclone	30-40	1		
			Low-resist. cyclone	20-30	1		
	Pulverized unit		Electrost. precipitator	80-99.9	1		
			High eff. cyclone	65-75	1		
			Low-resist. cyclone	40-60	1		
	Spreader stoker		High-eff. cyclone	85-90	1		
			Low-resist. cyclone	70-80	1		
			Settling chamber	20-30	1		
	Other stokers		High-eff. cyclone	90-95	1		
			Low-resist. cyclone	75-85	1		
			Settling chamber	25-50	1		

TABLE XVI-12 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 491

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Coal combustion	All	SO_x	Wet limestone	90	2.4[a]		276
			Dry limestone	67	5.8[b]		158
			Dolomite	95	2.4[c]		158
			Saleable product systems	90	1.53		433
Oil combustion	All	SO_x	Wet limestone	90	2.4[a]		276
			Dry limestone	67	5.8[b]		158
			Dolomite	95	2.4[c]		158
			Saleable product systems	90	1.53		433
Nuclear plants		Radioactive isotopes in water	Coagulation & sedimentation	40-70	1+		113
			Storage	99	1		
			Ion exchange	70-90	1		
		Air-borne isotopes	Filtration	70-95	n.d.		111
			Charcoal adsorption	90	1		
			Fluoro-carbon	98	1		
			Cryogenic charcoal adsorption	90	1		
			Cryogenic distillation	90	1		

TABLE XVI-12 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 491

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Nuclear plants (Cont.)	Disposal of wastes		Pot. calcination	99	0.15–0.5[d]		157
			Spray melt	99	0.45–1.33[d]		
			Phosphate glass	99	0.56–2.09[d]		
			Fluid bed	99	0.21–1.18[d]		
			Solidification	99	0.75[b]		

---

[a] See text for chemical derivation of kg residue per kg SO_x removed.

[b] Every mole of SO_2 removed from the emissions yields one mole of $CaSO_4$ plus 70/30 moles of waste limestone. The ratio of solid residues to SO_2 removed can then be calculated as:

	Item		Molecular Weight
	1 mole SO_2		64.07
Yields:	1 mole $CaSO_4$	=	136.15
	$\frac{70}{30}$ moles $CaCO_3$	=	234.0
	Total residue	=	370.15

Thus residues = 370.15/64.07 = 5.8 kg residues/kg SO_2 removed.

TABLE XVI-12 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE
SIC 491

c

Every mole of SO_2 removed by dolomite injection yields one mole of $CaSO_4$ + 0.1 mole of waste dolomite. (See equation 4 in text.) The ratio of solid residues to SO_2 removed can then be calculated as:

	Item	Molecular Weight
	1 mole SO_2 =	64.07
Yields:	1 mole $CaSO_4$	136.15
	1 mole $Ca Mg (CO_3)_2$	18.44
	Total residues	154.59

Thus residues = 154.59/64.07 = 2.4 kg residues/kg SO_2 removed.

d

kg per 10^6 kwh. See Table XVI-14 for derivation of these figures.

TABLE VI-13

LOW AND INTERMEDIATE LEVEL SOLID RESIDUES PER KWH FROM POLLUTION CONTROL IN NUCLEAR REACTORS

	Pressured Water Reactor (PWR)			Boiling Water Reactor (BWR)		
	m^3/600 MW[158]	kkg/ 600 MW [a]	$\frac{10^{-6}\ kg}{kwh.}$	m^3/600 MW[158]	kkg/600 MW[a]	$\frac{10^{-6}\ kg}{kwh}$
Used ion exchange	10 - 20	8.5 - 17	2.16-4.31	27	23	5.83
Slurries	-	-	-	60 - 80	51 - 68	12.94 - 17.25
Concentrate from evaporator	30 - 40	25.5 - 34	6.47-8.62	15	12.8	2.25
Used filters and equipment	10	8.5	2.16	3	2.6	0.66
Totals	50 - 70	42.5 - 59.5	10.79-15.09	105 - 125	89.4 - 106.4	21.68 - 25.99

[a] To convert from m^3 to kkg:
(1) 280 drums @ 200 liters/drum = 56,000 liters
(2) 56,000 liters = 45 kkg (Reference 158)
(3) $\frac{45\ kkg}{56,000\ l} = \frac{45\ kkg}{56\ m^3} = 0.8\ kkg/m^3$

TABLE XVI-14

HIGH LEVEL SOLIDIFIED SOLID WASTES PER KWH FROM REPROCESSING PLANTS[a]

Solidification Process	Volume liters/1000 MWd(e)[157] (MWd (t)/1.3)	Density mg/liter	kg/ 1000 MWd(e)	kg/kwh × 10^{-6}
Pot calcine	3.3 - 8.0	1.1 - 1.5	3.63 - 12.0	.15 - .50
Spray melt	4.0 - 10.0	2.7 - 3.2	10.8 - 32	.45 - 1.33
Phosphate glass	5.0 - 16.7	2.7 - 3.0	13.5 - 50.1	.56 - 2.09
Fluid bed	5.0 - 16.7	1.0 - 1.7	5.0 - 28.4	0.21 - 1.18
		Mean		.81

[a] Terminology:

MWd: megawatts per day
(e): electrical energy
(t): thermal energy

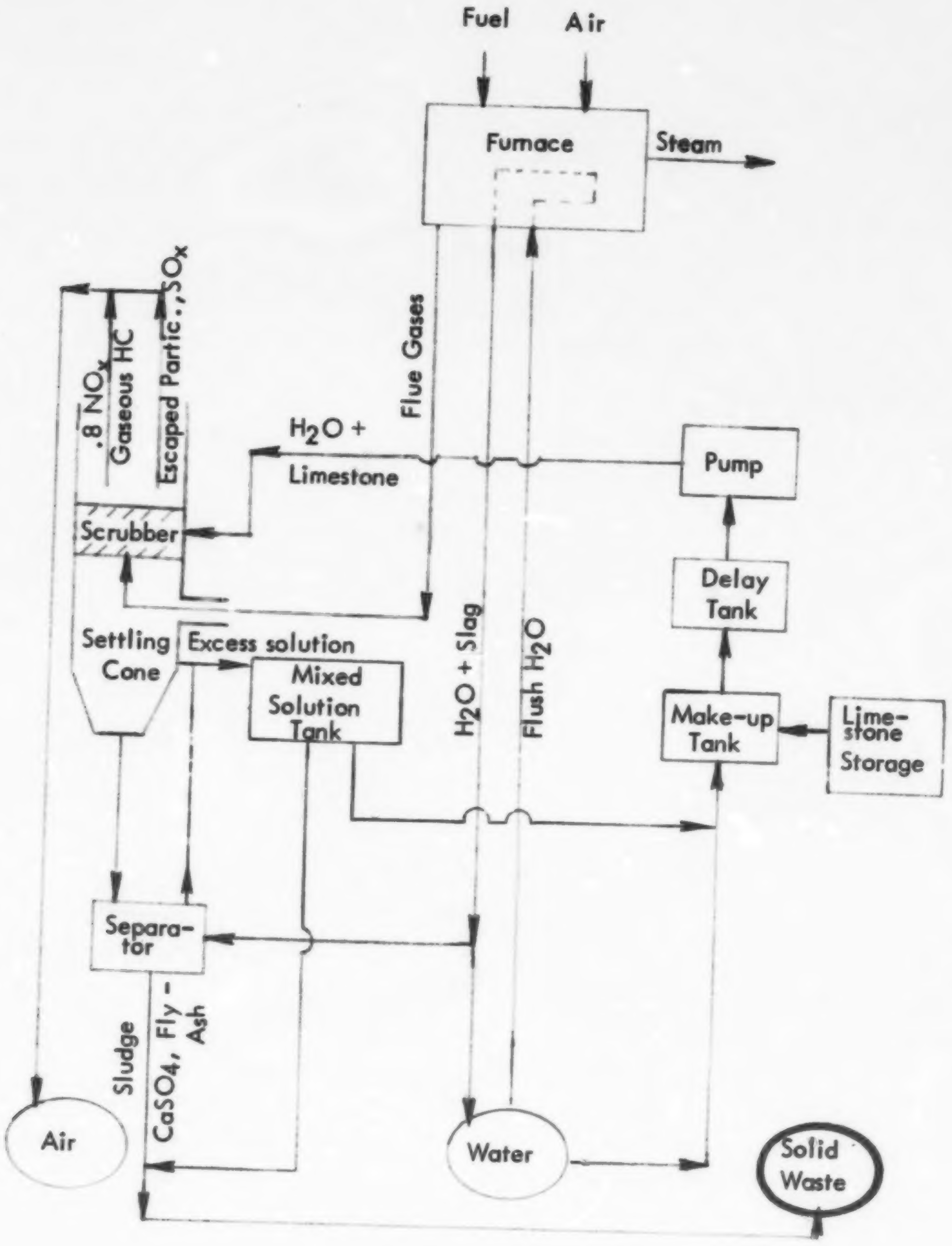
Fuel
Air
Furnace
Steam
Flue Gases
.8 NO_x
Gaseous HC
Escaped Partic., SO_x
H_2O +
Limestone
Pump
Scrubber
Delay Tank
Settling Cone
Excess solution
Mixed Solution Tank
H_2O + Slag
Flush H_2O
Make-up Tank
Lime-stone Storage
Separa-tor
Sludge
$CaSO_4$, Fly-Ash
Air
Water
Solid Waste

FIGURE XVI-3
AIR POLLUTION TREATMENT SCHEMATIC:
WET LIMESTONE SCRUBBING
IN FOSSIL FUEL PLANTS

$$\text{(XVI-1)}\quad CaCO_3 + SO_2 \longrightarrow CaSO_3 + CO_2$$

$$\text{(XVI-2)}\quad CaSO_3 + \frac{1}{2}O_2 \longrightarrow CaSO_4$$

For every kilogram of SO_2 removed, 2.4 kg of $CaSO_4$ are produced.[276] Very little waste limestone is included with total wastes from this process. The stoichiometric ratio is close to the actual ratio for solid residues to SO_x removed.[5] Table XVI-15 lists the primary costs and material inputs for wet limestone scrubbing.

Dry limestone scrubbing (shown in Figure XVI-4) operates at 30 percent stoichiometric and 67 percent removal efficiency. The need for water conservation is the main justification in the use of dry limestone control. The basic reaction for this process is listed in Equation XVI-3 below:

$$\text{(XVI-3)}\quad SO_2 + CaCO_3 + \tfrac{1}{2}O_2 \longrightarrow CaSO_4 + CO_2$$

Every mole of SO_2 removed from the emissions yields one mole of $CaSO_4$ plus 2.3 moles of waste limestone.

Dolomite injection plus wet scrubbing are very near to stoichiometric and remove nearly 95 percent of the SO_x, with only 110 percent of the stoichiometric equivalent of dolomite.[6] This is a two-step process, with the reaction shown in Equation XVI-4:

$$\text{(XVI-4)}\quad CaMg(CO_3)_2 + 2SO_2 + O_2 \longrightarrow CaSO_4 + MgSO_4 + 2CO_2$$

Every two moles of SO_2 removed by dolomite injection yield one mole of $CaSO_4$ and one mole of $MgSO_4$, plus 0.1 mole of waste dolomite. However, dolomite injection is generally inferior to wet limestone scrubbing due to the cost of equipment, maintenance, and consumables.

Figure XVI-5 illustrates the disposal alternatives for scrubber systems in electric power plants. Settling pond sand sludge concentrations normally yield solid waste for landfill disposal.

Significant regeneration processes do not exist for any of the above reactants. Research in the area of regenerating limestone might prove rewarding. The large quantity of solid waste generated from this sector could be significantly reduced by regenerating limestone.

Saleable Product Systems. The magnesium oxide (MgO) scrubbing process was the first major flue gas cleaning system that generated saleable products. The basic MgO process utilizes an aqueous slurry of magnesium oxide, magnesium sulfite, and magnesium sulfate to scrub SO_2 from flue gas streams. The major reaction involves formation of additional magnesium sulfite through combination of SO_2 and magnesium oxide. Magnesium sulfite removed from the scrubber loop is dried and subsequently calcined to drive off SO_2 and regenerate active MgO for return to the scrubber loop. The SO_2 generated in the calcining operation can be converted to a high-grade sulfuric acid or to elemental sulfur

TABLE XVI-15

WET LIMESTONE PROCESS REQUIREMENTS/METRIC TON OF COAL PROCESSED 6[a]

Factor	Requirement
Water	704 liters
Electricity	15.6 kwh
Limestone	120 kg
Direct labor	$0.210 or 0.74 man-hrs
Plant maintenance	
Labor	$0.184 or 0.58 man-hrs
Material	$0.095
Payroll overhead	$0.069
Operating supplies	$0.040
Taxes plus loss	$0.084
Depreciation	$0.155

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[a] Total cost/metric ton of coal including water, electricity and limestone = $2.13/metric ton. Assumes 5 percent sulfur coal and 90 percent control.

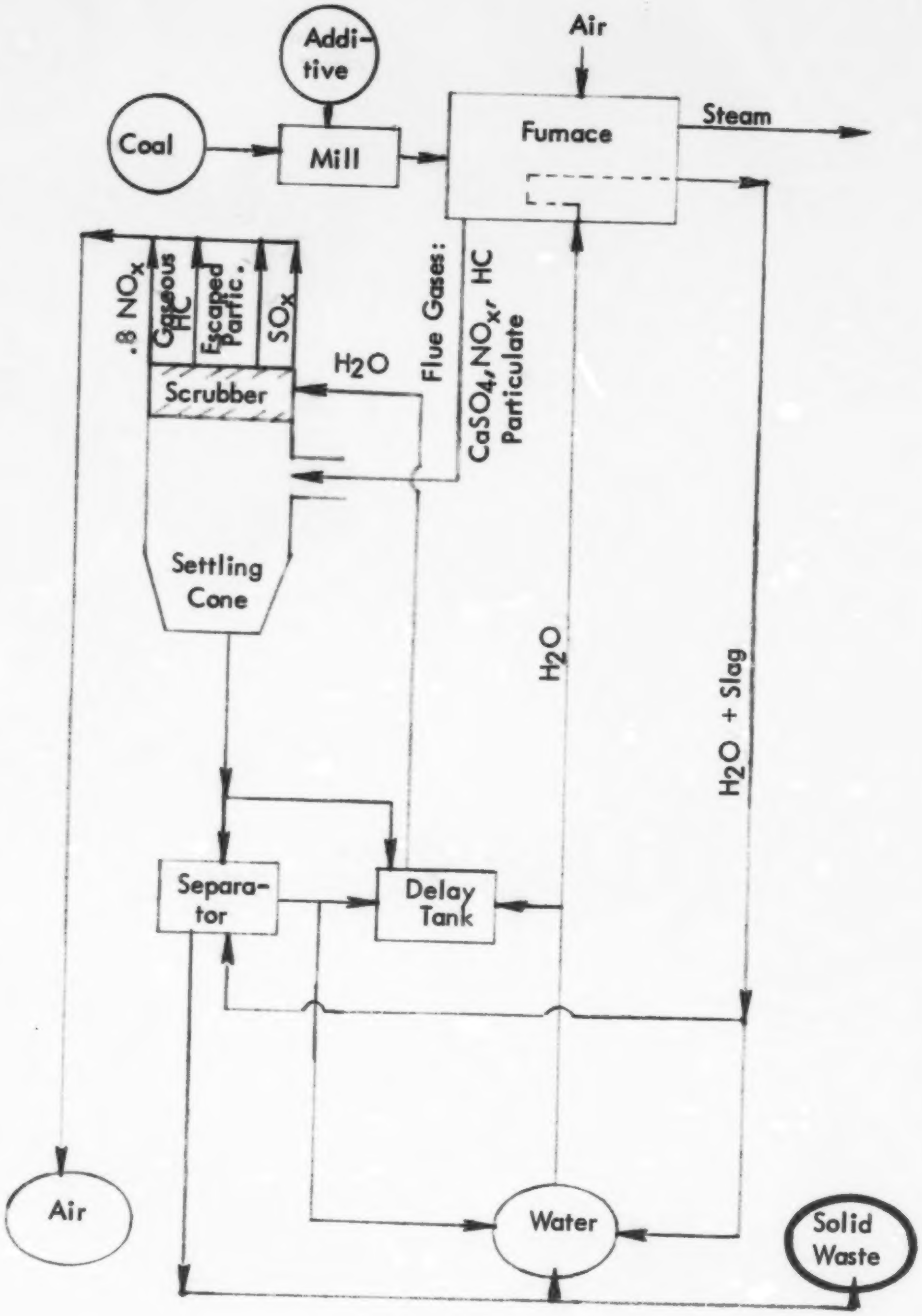

Additive
Air
Coal
Mill
Fumace
Steam
.8 NO$_x$
Gaseous HC
Escaped Partic.
SO$_x$
H_2O
Scrubber
Flue Gases: CaSO$_4$, NO$_x$, HC Particulate
Settling Cone
H_2O
H_2O + Slag
Separator
Delay Tank
Air
Water
Solid Waste

FIGURE XVI-4
AIR POLLUTION TREATMENT SCHEMATIC:
DRY LIMESTONE SCRUBBING
IN FOSSIL FUEL PLANTS

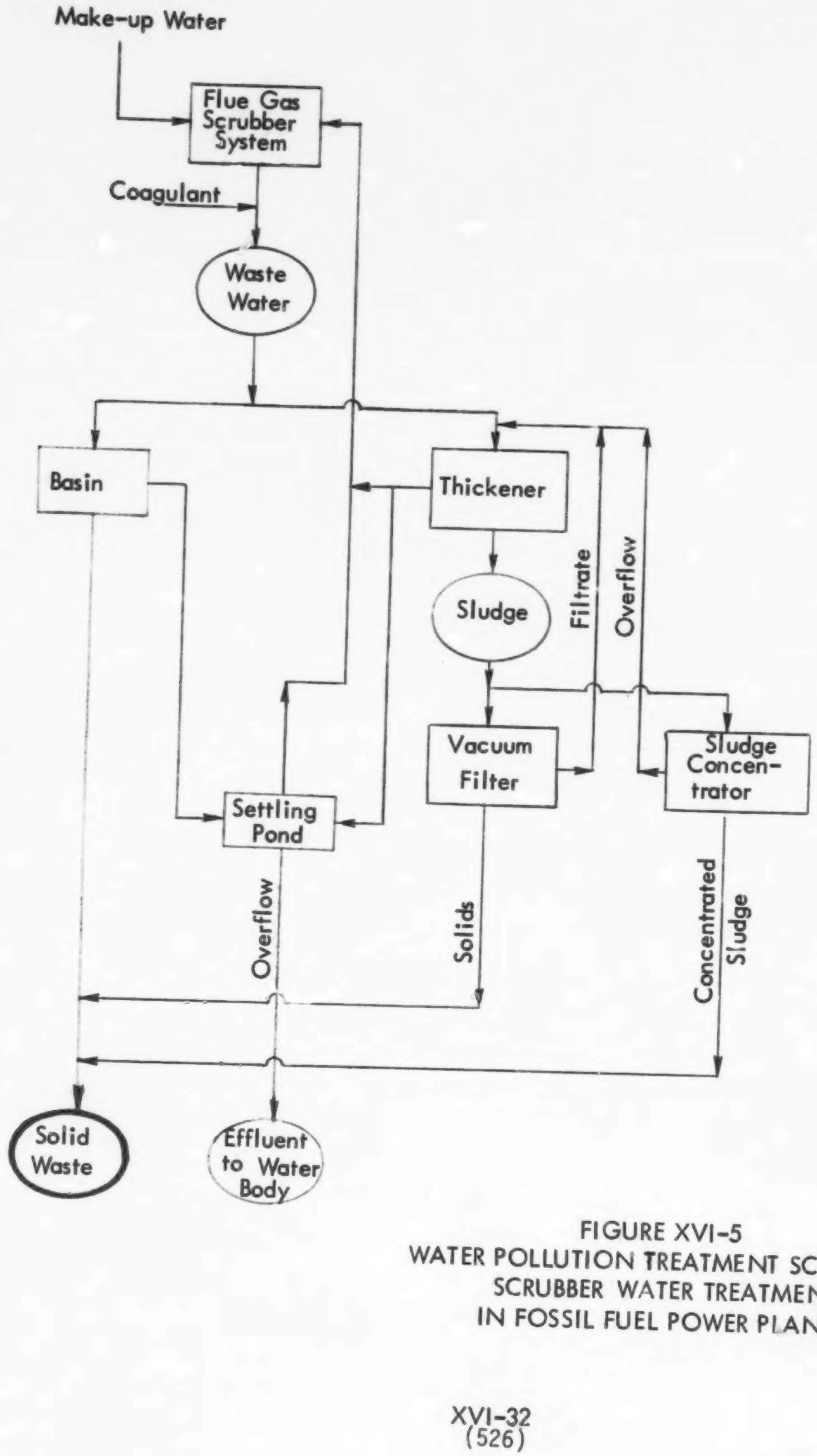

Make-up Water
Flue Gas Scrubber System
Coagulant
Waste Water
Basin
Thickener
Sludge
Filtrate
Overflow
Vacuum Filter
Sludge Concen-trator
Settling Pond
Overflow
Solids
Concentrated Sludge
Solid Waste
Effluent to Water Body

FIGURE XVI-5
WATER POLLUTION TREATMENT SCHEMATIC:
SCRUBBER WATER TREATMENT
IN FOSSIL FUEL POWER PLANTS

with appropriate subsequent equipment.[433] Although this system suffers from a lack of reliable, long-term operating experience and a lack of experience with coal-fired power plants, it offers a promising approach for reducing solid residues produced in the conventional throw-away flue gas cleaning devices.

The Wellman-Lord SO_2 recovery process utilizes a sodium sulfite-sodium bisulfite solution to absorb SO_2 from flue gas. The spent absorbent, rich in bisulfite, is processed in a steam-heated evaporator, which regenerates active sodium sulfite crystals and produces a stream of SO_2 for further processing. The basic process is depicted in Equations XVI-5 (absorption) and XVI-6 (regeneration) below:

$$\text{(XVI-5)} \quad SO_2 + Na_2SO_3 + H_2O \longrightarrow 2\,Na\,HSO_3$$

$$\text{(XVI-6)} \quad 2\,NaHSO_3 \xrightarrow[\text{heat}]{} Na_2\,SO_3 + SO_2 + H_2O$$

The SO_2 is used to produce sulfuric acid yielding a final residue to pollutant ratio of 1.53 kg residue per Kg pollutant.

The catalytic oxidation process converts most of the SO_2 present in the flue gas stream to SO_3 for subsequent removal by an acid-absorption tower. The concentration of the acid produced in the absorbing tower is approximately 80 percent; this is suitable primarily for use in fertilizer production.[433]

Of 44 flue gas desulfurization systems under construction or planned as of September, 1973, only 6 are planned to be saleable product systems (three magnesium oxide), while 33 are throw-away product systems; 5 have not yet been selected.[433] These statistics, however, obviously cover only a small percentage of the 970 fossil-fuel generating plants in the U.S. The breakdown of future applications of these alternative systems is uncertain, depending on pressures for reduced land disposal system costs, the price of sulfuric acid, and future development of technologies for alternative methods.

Particulates. Control of particulates is by electric precipitation, dry scrubbing, and wet scrubbing. In 1971 no SO_x control was exercised, so that special attention to particulates was required; by 1980 the introduction of SO_x control by wet limestone scrubbing will probably remove particulates with over 95 percent efficiency. Dry and wet scrubbing are used currently when coal is used as fuel, and good particulate control systems will be required by 1980, especially to control colloidal range fines.

Carbon Monoxide and Nitrogen Oxides. Carbon monoxide is a relatively insignificant pollutant by weight in fossil-fuel power plant emissions. It is conceivable, though, that the control of nitrogen oxides by low excess air and lower temperature furnace processes may somewhat increase this pollutant.

Control of nitrogen oxide emissions from fossil fuel power plants is unlikely to create significant amounts of solid residues, even though relatively large amounts of these pollutants are discharged following combustion. Four possibilities exist for NO_x control: lower-temperature combustion; reduction of excess air during combustion; stack gas treatment removal from flue and tail gases; and catalytic decomposition. The first two alternatives are the most likely to be applied in the future,[24] and neither results in solid waste residues being created. Stack gas scrubbing, if developed after 1985, would create nitrate salt residues, while catalytic composition would not, but neither of these methodologies is forecast to be in use before 1985.

Nuclear Plant Air Pollution Control. The main method of air pollution control in the nuclear nuclear power industry consists of temporary holding until radioactivity decreases to safer levels. The radioactive wastes in air are short-lived (about one-half hour), except for a few long-lived isotopes. Today most airborne isotopes are diluted and allowed to escape through very high stacks. Presently, a few separation methods exist that will isolate gaseous radioactive fission by-products from the air. Amounts of gases isolated are very small, and the isotopes so short-lived that the gases are typically released within several days. (See Figures XVI-6 and XVI-7.)

Water Pollution Control. Controls for water pollution are not as advanced as those for air in the electric power industry. Ash and solids resulting from SO_x control are decanted in settling basins. These then yield solid residues. The soluble pollutants resulting from other operations in fossil-fuel plants are usually not removed, but are sent directly to water bodies without treatment, dilution, or neutralization. Soluble pollutants may be further reduced if the effluents are routed through sewage treatment facilities. Future standards may, however, require further treatments. Pattersen, Bantis, and Kim have evaluated possible recycling and treatment schemes that might be required in the future. "In view of the present Federal and State restrictions for wastewater discharges to receiving streams and the zero pollution standards anticipated by 1985, ... recycle principles can be used as system design guides for meeting wastewater discharge criteria and, at the same time, minimizing dependence on outside water sources."[25]

Water pollutants from fossil-fuel power plants arise mainly from the following sources:[23]

(1) Heated cooling water causing thermal pollution.
(2) Hot, concentrated water salines from boiler and evaporator blow-down.
(3) Acid and alkaline chemical solutions used in cleaning power-plant equipment.
(4) Water from blow-down of cooling towers containing minerals in high concentrations.
(5) Wastewater from washing stack gases.
(6) Acid and caustic solutions resulting from the regeneration of ion-exchange softeners and demineralization water treatment plants, the latter of which are used for conditioning feed water for boilers and evaporators.

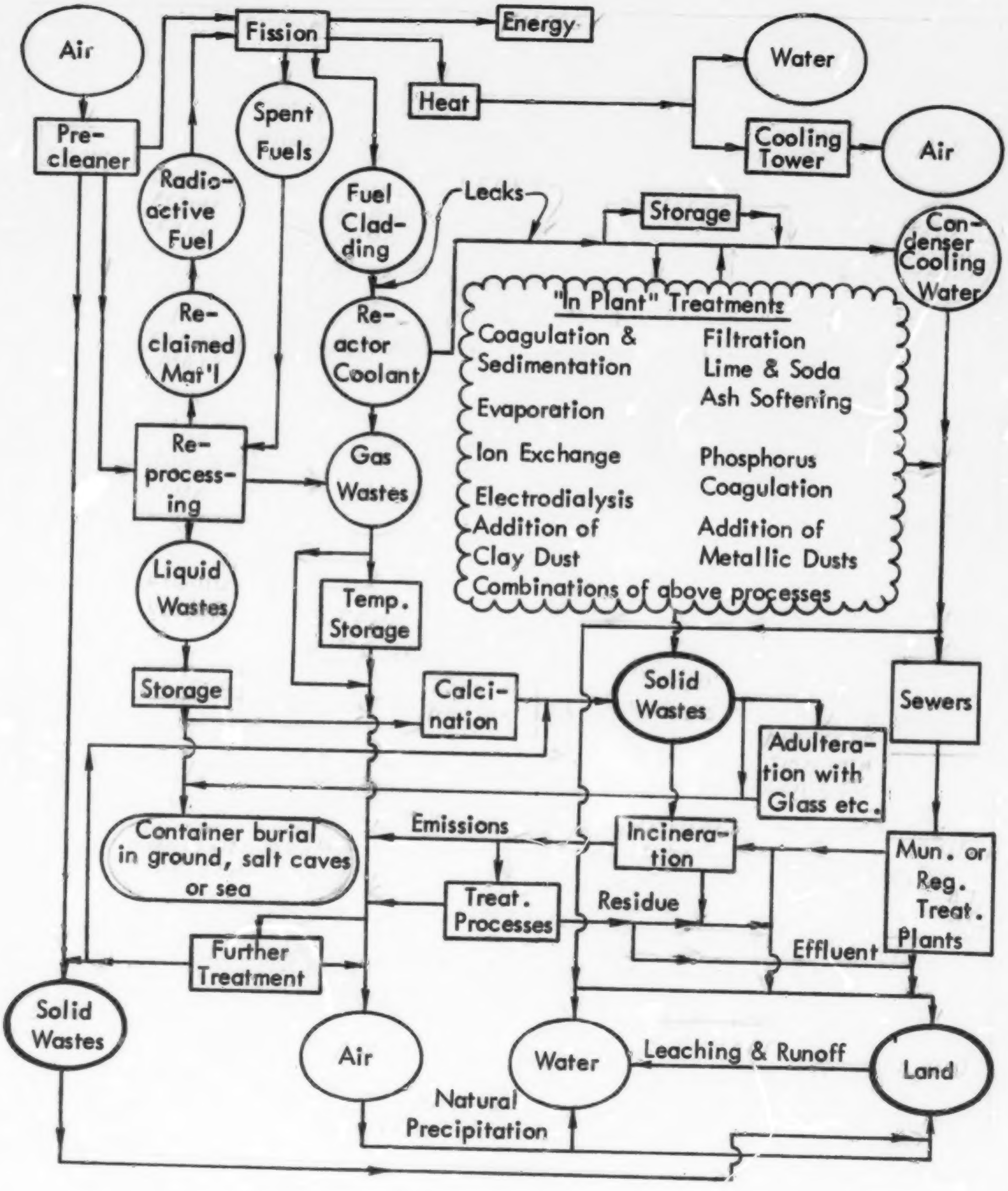

Air
Pre-cleaner
Fission
Energy
Heat
Water
Cooling Tower
Air
Spent Fuels
Radio-active Fuel
Fuel Clad-ding
Leaks
Storage
Con-denser Cooling Water
Re-claimed Mat'l
Re-actor Coolant
"In Plant" Treatments
Coagulation & Sedimentation
Filtration
Lime & Soda Ash Softening
Evaporation
Ion Exchange
Phosphorus Coagulation
Electrodialysis
Addition of Clay Dust
Addition of Metallic Dusts
Combinations of above processes
Re-process-ing
Gas Wastes
Liquid Wastes
Temp. Storage
Storage
Calci-nation
Solid Wastes
Sewers
Adultera-tion with Glass etc.
Container burial in ground, salt caves or sea
Emissions
Incinera-tion
Mun. or Reg. Treat. Plants
Treat. Processes
Residue
Effluent
Further Treatment
Solid Wastes
Air
Water
Leaching & Runoff
Land
Natural Precipitation

FIGURE XVI-6
AIR AND WATER POLLUTION TREATMENT SCHEMATIC: NUCLEAR POWER PLANTS

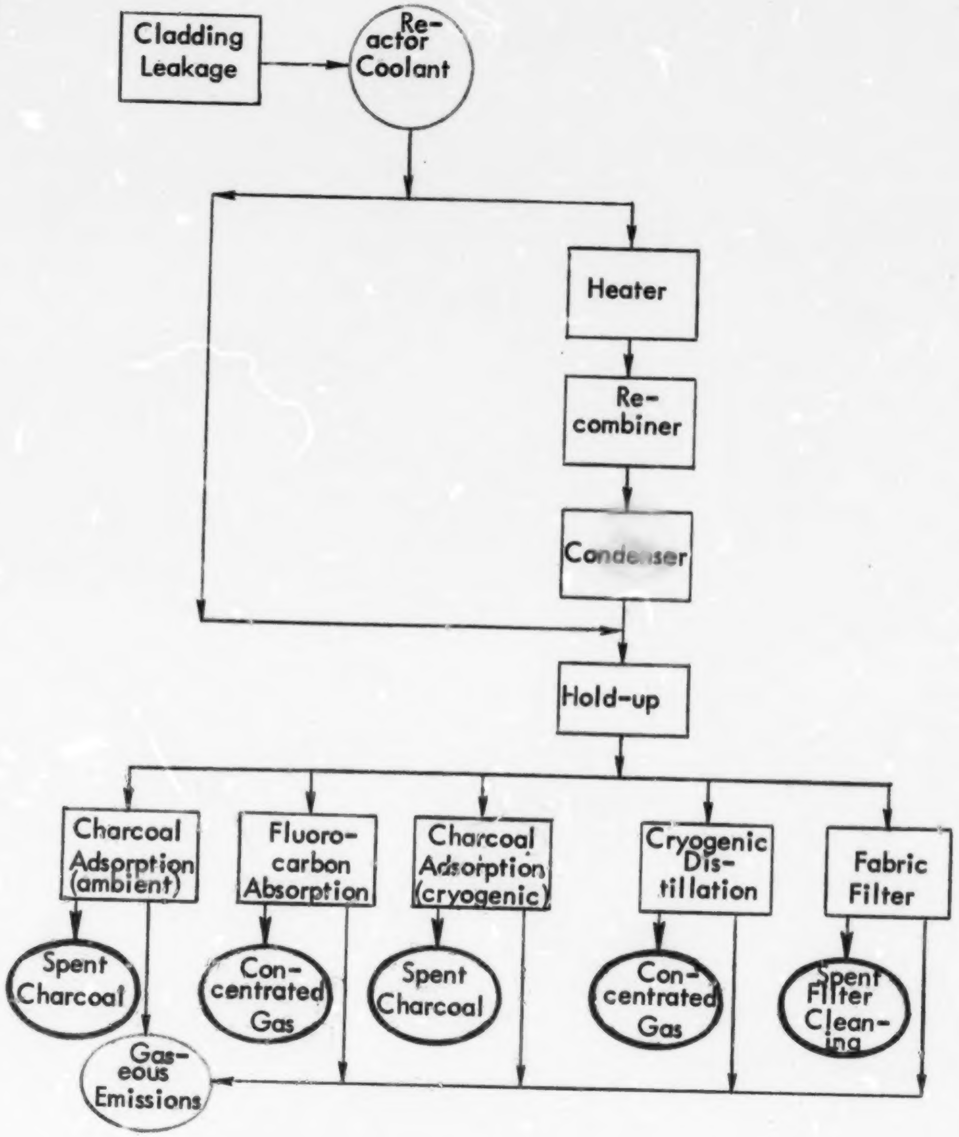

Cladding Leakage
Reactor Coolant
Heater
Re-combiner
Condenser
Hold-up
Charcoal Adsorption (ambient)
Fluoro-carbon Absorption
Charcoal Adsorption (cryogenic)
Cryogenic Distillation
Fabric Filter
Spent Charcoal
Concentrated Gas
Spent Charcoal
Concentrated Gas
Spent Filter Cleaning
Gaseous Emissions

FIGURE XVI-7
ADVANCED AIR POLLUTION
TREATMENT SCHEMATIC:
NUCLEAR POWER PLANTS

(7) Hot alkaline water from blowing down chemical softening plants.
(8) Acid water drainage from coal storage.
(9) Drainage from cinder and ash dumps.
(10) Sanitary sewage.
(11) Oil, greases, and miscellaneous solid and liquid wastes.

Currently, steam power plants often use settling ponds to control solids resulting from washing particulates and sulfur oxides from stack gases, and from hydraulic removal of furnace ash. Equalization and neutralization procedures are used to control the other wastes.[25] These processes are largely intramedial in that they do not remove the pollutants, but stabilize them. Since some steam plant wastes are acid and some are alkaline, equalization can aid in controlling pH. Where the balance is not sufficient, neutralization is used. With the increasing pressure for zero discharge, recycling has become more attractive.

Where circulating water is not recycled, many plants simply dilute these wastes with the circulating water. More stringent requirements have made future application of this procedure infeasible, however. Wastewater control alternatives likely to be used in the future(as outlined by Patterson, Banks, and Kim) will be discussed below.

Alternative ways of handling the water-borne wastes from the flue gas scrubbing system are illustrated in Figure XVI-5. Thickeners and sludge filters can be used instead of settling ponds, or as a supplement to them. Their cost is high, however, and their cost effectiveness has not yet been proven. Dissolved solids are the most important problem with the condenser cooling system. In most cases the tower blow-down can be used for direct reuse in the ash handling and flue gas systems. Where continuous blow-down procedures are used, water may be recycled into the ash removal and flue gas systems. The resulting pH and hardness problems will eventually require treatment of minerals and other pollutants. Intermittent discharges are not suitable for recycling, and will probably be discharged after equalization and neutralization. Control of coal pile and yard drainage can consist of surface skimming, settling ponds, and neutralization. Some authors suggest a rapid return to streams while the flow is still high from rainfall, suggesting a preference toward dilution.[22] Reverse osmosis plants may be necessary for terminal treatment of recycled wastewaters before discharge to receiving streams, with the required preliminary clarifiers, filters, and neutralization steps.[25] (See Figure XVI-6.) This determines the final form of the wastes, aside from ash, sulfur-compounds, and dissolved solids removed from the effluents in previous steps. The waste stream would then flow through an evaporator for silt removal.

The content of the wastes generated from fossil-fuel power plants is clearly more important than their total weight. The total of all daily wastes is typically equal to 3,336 kilograms per day for a 500 MW plant. This type of plant would require 225 kkg per hour of coal at 0.5 kg/kwh. For an 18-hour day, this would amount to 4,080 kkg of coal. This amount of coal would yield around 410 kkg of ash and another 410 kkg or so of calcium sulfate and sulfite if wet limestone scrubbing were used. The precipitation of these wastes, then, is the most important impact upon land disposal. Nevertheless,

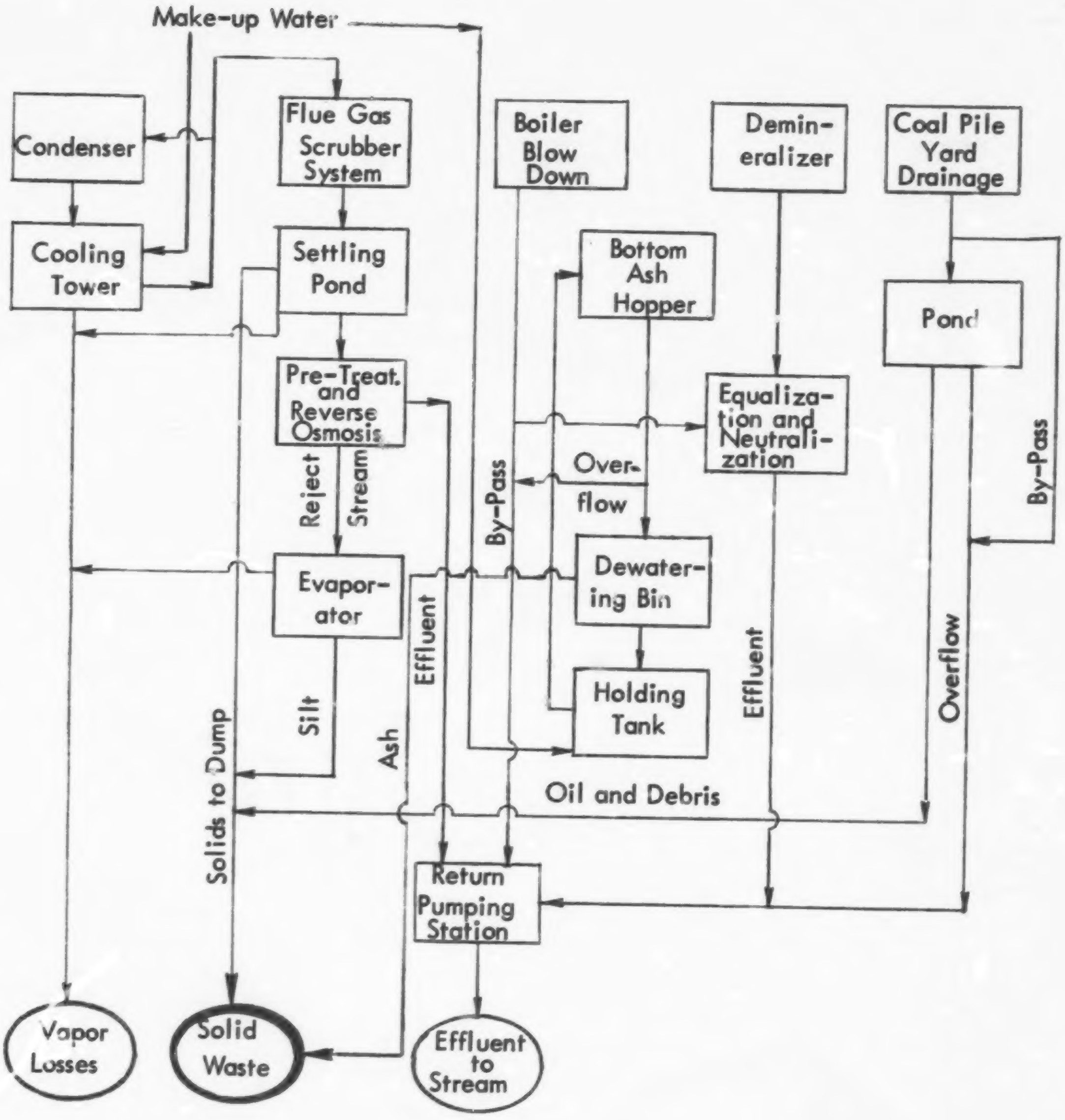

Make-up Water
Condenser
Flue Gas Scrubber System
Boiler Blow Down
Demin- eralizer
Coal Pile Yard Drainage
Cooling Tower
Settling Pond
Bottom Ash Hopper
Pond
Pre-Treat. and Reverse Osmosis
Equaliza- tion and Neutrali- zation
Over- flow
Reject Stream
By-Pass
By-Pass
Evapor- ator
Dewater- ing Bin
Effluent
Effluent
Overflow
Silt
Solids to Dump
Ash
Holding Tank
Oil and Debris
Return Pumping Station
Vapor Losses
Solid Waste
Effluent to Stream

FIGURE XVI-8
ADVANCED WATER POLLUTION
TREATMENT SCHEMATIC:
FOSSIL FUEL POWER PLANTS

periodic cleanout of the boilers and the chemicals involved can create problems for landfills.

Water from radiation-contaminated areas of a nuclear fission plant are treated with filters and chemical softeners to remove the ions and minerals that produce radiation. (See Figures XVI-6 and XVI-9) This produces liquid and solid wastes that are either diluted and released or stored for a long time in isolation from the environment. The future method of water treatment will be solidification by one of the methods currently under study. Solidifying liquid wastes eliminates tank corrosion and the danger from leaks, reduces volume, and lowers ultimate storage costs.

Forecast treatment data may be given a confidence level of 4 for fossil fuel plants, indicating a ten percent variation in the data and a confidence level of 2 for nuclear power plants, indicating a possible 50 percent variation.

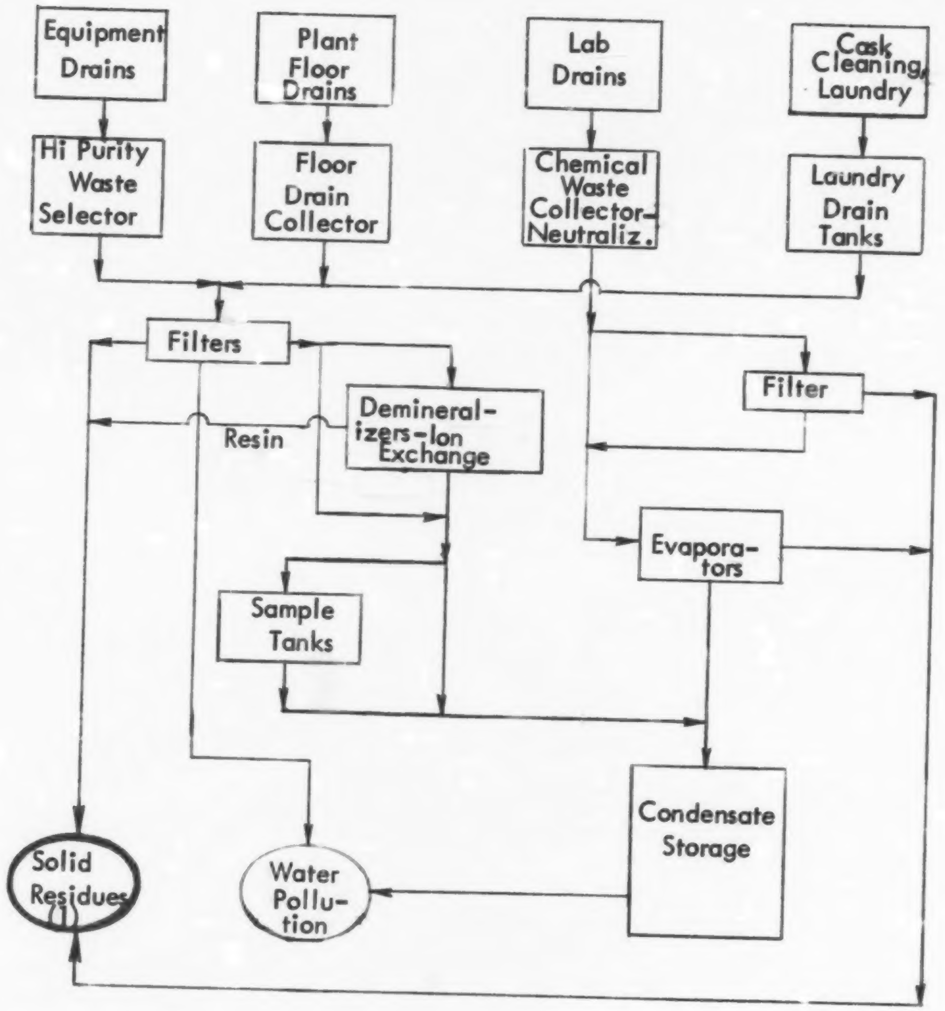
Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

The solid wastes produced in quantity from electric power plants are Ca SO_x, particulates, and radioactive media. None of these wastes is currently being reused in great quantity. (See Table XVI-16.) The potential for the application of saleable product flue gas cleaning devices was discussed in the previous section. These systems primarily produce the saleable by-product sulfuric acid. The main doubt concerning sulfuric acid recovery systems is that the increased use of such systems is likely to produce a glut of sulfuric acid on the market, driving down prices and making sulfuric acid recovery less economically feasible. Recent indications suggest that the sulfuric acid produced from the control of sulfur oxides in petroleum refineries and other sources, added to that produced by controls in the power industry (if they are in fact implemented), will in fact far exceed the market demand,resulting in the elimination of the independent sulfuric acid manufacturing industry were all sulfuric oxides converted to sulfuric acid. Because of the low resulting price of sulfuric acid, the application of these saleable product processes has been limited in the future to 20 percent of the total on power plant sulfur oxide treatment applications.

It is unlikely that radioactive wastes will ever be reusable; Ca SO_x may eventually be reused. Estimates of reuse of solid wastes residues from individual treatment processes can be given a confidence level of 4, indicating a ± 10 percent variation.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables XVI-17 through XVI-20 forecast the estimated amounts of solid wastes produced from air and water pollution control through 1985. The vast majority of solid residues, even in 1985 when nuclear reactors are forecast to become more prevalent, will be generated from fossil-fuel power plants. In these final forecast tables, solid waste generated from SO_x and particulate scrubbing derived at fossil-fuel power plants are considered. These latter residues are transferred from air to water, after which settling basins (with approximately 90 percent efficiency) remove them from the scrubber water.


Equipment Drains
Plant Floor Drains
Lab Drains
Cask Cleaning, Laundry
Hi Purity Waste Selector
Floor Drain Collector
Chemical Waste Collector-Neutraliz.
Laundry Drain Tanks
Filters
Filter
Demineral-izers-Ion Exchange
Resin
Evapora-tors
Sample Tanks
Condensate Storage
Solid Residues (1)
Water Pollu-tion

(1) Filter media, concentrated wastes from - de-ionization, evaporator residues

FIGURE XVI-9
ADVANCED WATER POLLUTION TREATMENT SCHEMATIC: NUCLEAR POWER PLANTS

TABLE XVI-16
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC 491

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Electric power generation					
sulfur oxides	Coal	Throw away flue gas systems	0	276	$CaSO_4$, $CaSO_3$, $CaCO_3$, $Ca(OH)_2$
	Oil		0	276	$CaSO_4$, $CaSO_3$, $CaCO_3$, $Ca(OH)_2$
	Gas		0	276	$CaSO_4$, $CaSO_3$, $CaCO_3$, $Ca(OH)_2$
	Coal	Saleable product flue gas cleaning systems	100	433	Sulfuric acid
	Oil		100	433	Sulfuric acid
	Gas		100	433	Sulfuric acid
particulates	Coal	Combined treatment with SO_x control or pre-treatment with scrubber or baghouses	0	276	Ash
	Oil		0	276	Ash
	Gas		neg.	276	Ash
radioactive wastes	Nuclear	All	0	237	Organic and inorganic gases, liquids and solids

TABLE XVI-17
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 491

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Coal		Scrubber	100	(33,500)[a]	85	(28,500)	to water treatment	
Oil		None	n.a.	0	n.a.	0	n.a.	0
Gas		None	n.a.	0	n.a.	0	n.a.	0
Sub-total				(33,500)	85	(28,500)		(28,500)
Sulfur oxides:								
Coal		None	n.a.	0	n.a.	0	n.a.	0
Oil		None	n.a.	0	n.a.	0	n.a.	0
Gas		None	n.a.	0	n.a.	0	n.a.	0
Sub-total				0		0		0
Total Residues from Air Pollution Control:								0
WATER POLLUTANTS								
Total solids:								
Fossil fuels		Settling ponds	100	28,500	90	25,600	100	25,600
Total Residues from Water Pollution Control (Fossil Fuels):								25,600
AIR AND WATER POLLUTANTS								
All: nuclear power plants		Air and water pollution controls	100	0.73	100	0.73	100	0.73
Total Residues from Air and Water Pollution Controls:				33,500	76	25,600	100	25,600

TABLE XVI-17 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 491

[a] Residues created during scrubbing are transferred to water as suspended solids, where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid waste is evaluated in the water pollutant estimates since no solid wastes are created until water treatment occurs following intermedial transfer.

TABLE XVI-18
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 491

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Coal		Dry treatment	50	20,200[a]	85	17,200	100	17,200
		Scrubber	50	(20,200)	95	(19,190)	to water treatment	
Oil		Scrubber	25	(20)	95	(20)	to water treatment	
Gas		None	100	0	n.a.	0	n.a.	0
Sub-total				(40,420)	90	(36,410)	100	(36,410)
Sulfur oxides:								
Coal		Wet limestone	40	(19,360)	90	(17,420)	to water treatment	
		Saleable prod.	10	3,090	90	2,780	0	0
Oil		Wet limestone	20	(2,640)	90	(2,380)	to water treatment	
		Saleable prod.	5	420	90	380	0	0
Gas		None	100	0	n.a.	0	n.a.	0
Sub-total				(25,510)	90	(22,960)	100	(22,960)
Total Residues from Air Pollution Control:								17,200
WATER POLLUTANTS								
Total solids:								
Fossil fuels		Settling ponds	100	39,010	90	35,110	100	35,110
Total Residues from Water Pollution Control (Fossil Fuels)								35,110
AIR AND WATER POLLUTANTS								
All: nuclear power plants		Air and water pollution controls	100	4.3	100	4.3	100	4.3

TABLE XVI-18 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC 491

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Total Residues from Air and Water Pollution Controls				65,930	84	55,470	94	52,310

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[a] Refer to footnote (a),Table XVI-17.

TABLE XVI-19
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 491

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Coal		Scrubber	100	(49,300)[a]	95	(46,840)	To water treatment	
Oil		Scrubber	95	(140)	95	(130)	To water treatment	
Gas		Scrubber	50	(20)	95	(70)	To water treatment	
Sub-total				(49,460)	95	(46,990)	100	(46,990)
Sulfur oxides:								
Coal		Wet limestone	80	(47,200)	90	(42,480)	To water treatment	
		Saleable prod.	20	7,530	90	6,780	0	0
Oil		Wet limestone	75	(13,110)	90	(11,800)	To water treatment	
		Saleable prod.	20	2,230	90	2,010	0	0
Gas		Scrubber	50	(neg.)	n.d.	(neg.)	To water treatment	
Sub-total				(70,070)	90	(63,070)	100	(63,070)
Total Residues from Air Pollution Control								0
WATER POLLUTANTS								
Total solids:								
Fossil fuels		Settling ponds	100	101,320	100	101,320	100	101,320
Total Residues from Water Pollution Control (Fossil Fuels)								101,320

TABLE XVI-19 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC 491

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR AND WATER POLLUTANTS								
All:	nuclear power plants	All air and water pollution controls	100	10	100	10	100	10
Total Residues from Air and Water Pollution Controls				119,540	92	110,120	92	101,330

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[a] Refer to footnote (a), Table XVI-17.

TABLE XVI-20
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1985: SIC 491

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6: Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANTS								
Particulates:								
Coal		Scrubber	100	(65,600)[a]	95	(62,320)	To water treatment	
Oil		Scrubber	95	(200)	95	(190)	To water treatment	
Gas		Scrubbers	50	(20)	95	(20)	To water treatment	
Sub-total				(65,820)	95	(62,530)	100	(62,530)
Sulfur oxides:								
Coal		Wet limestone	80	(62,960)	90	(56,660)	To water treatment	
		Saleable prod.	20	10,040	90	9,040	0	0
Oil		Wet limestone	75	(18,160	90	(16,340)	To water treatment	
		Saleable prod.	20	3,090	90	2,780	0	0
Gas		Scrubber	50	neg.	n.d.		To water treatment	
Sub-total				(94,250)	90	(84,820)	100	(84,820)
Total Residues from Air Pollution Control								
WATER POLLUTANTS								0
Total solids:								
Fossil fuels		Settling ponds	100	135,530	100	135,530	100	135,530
Total Residues from Water Pollution Control (Fossil Fuels)								135,530

TABLE XVI-20 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 491

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR AND WATER POLLUTANTS								
All: nuclear power plants		All air and water pollution controls	100	23.1	100	23.1	100	23.1
Total Residues from Air and Water Pollution Controls				160,090	92	147,370	91	135,550

---

[a] Refer to footnote (a), Table XVI-17.

Although the solids pass through two media, they are considered as derived from air pollution control since their original form was that of particulates and sulfur oxides in the air.

Total residues generated from pollution control in electric power generation are forecast to increase from 25.6 billion kg in 1971 to 135.6 billion kg in 1985; this is greater than a five-fold increase. The large absolute quantities of solid wastes from pollution control by this sector are a result of two main factors: the relatively high efficiency of the scrubber and subsequent sedimentation processes in removing particulates and sulfur oxides from the air; and the very large amount of these latter pollutants originally present in the stack gases. The increases in solid waste residues from pollution control activities with time are attributable to expected increased enforcement and to the tremendous predicted growth rate of the industry between 1971 and 1985. The data in the final forecast section may be given a confidence level of 2, indicating a ± 50 percent possible variation.

Composition of Solid Waste Residues from Pollution Treatment Processes.

As shown in Table XVI-21, the major chemical components of coal fly ash are SiO_2 (approximately 40 percent), Al_2O_3 (approximately 26 percent), and Fe_2O_3 or Fe_3O_4 (approximately 14 percent). Other components are oxides of Ca, Mg, K, Na, Ti, carbonates and phosphates. Heavy metals are present and may pose a toxicity hazard.[276] The density of fly ash varies from 0.64 kg/l (dry, uncompacted)[156] to 1.4 (dry, wetted-compacted coal ash).[276]

The compositions of the lime and limestone sludges generated by scrubbing flue gases are listed in Tables XVI-22 and XVI-23. As may be seen, lime and limestone sludges are similar in most parameters, but differ in the content of hydrated calcium salts, calcium hydroxide, and calcium carbonate.

Factors Affecting Quality of the Data.

The composition of the fuel used for power generation greatly affects the accuracy of the data. The total energy production forecasts through 1985 are fairly reliable, but the individual production levels are unstable due to new research efforts, the increasing cost of energy sources, and the extensively-publicized potential hazards of fission power.

Sulfur content of fossil fuels is a prime factor affecting the data on solid waste generation potential of these fuels. The current National average sulfur concentration is between 2 and 3 percent. The low-sulfur fuels are used primarily in urban centers and the high-sulfur fuels are largely used in rural surroundings. A National average of 2.5 percent sulfur was used for the present forecasts. Since the residues of solid waste due to SO_x control are generated in direct proportion to the content of sulfur in the fuel, a change of forecast amounts of solid waste due to SO_x control can be accomplished by multiplying by a ratio of desired over 2.5 percent sulfur content.

TABLE XVI-21

RANGES IN ANALYSIS OF FLY ASH[9]

Compound	Percentage of fly ash; estimates from four sources (1)	(2)	(3)	(4)
Carbon, C	0.37-36.2	0.56-31.56[a]	1.4-13.5[a]	1.49-19.51[a]
Iron, Fe_2O_3 or Fe_3O_4	2.0 -26.8	3.86-26.43	6.1- 9.0	6.62-26.43
Magnesium, MgO	0.06- 4.77	0.55- 1.91[b]	1.3- 2.0	0.55- 1.63
Calcium, CaO	0.12-14.73	1.00-10.59	2.6- 4.3	0.99- 9.68
Aluminum, Al_2O_3	9.81-58.4	15.12-34.04	26.7-28.5	17.50-30.39
Sulfur, SO_3	0.12-24.33	0.23- 3.59[c]	-	0.23- 3.59
Titanium, TiO_2	0.50- 2.8	-	-	-
Carbonate, CO_3	0.05- 2.6	-	-	-
Silicon, SiO_2	17.3-63.6	28.1 -51.26	45.2-46.9	34.01-47.54
Phosphorus, P_2O_5	0.07-47.2	-	-	-
Potassium, K_2O	-	-	2.8- 3.0	-
Sodium, Na_2O	-	-	0.2- 0.9	-
Undetermined	0.08-18.9	-	-	-

[a] Ignition loss.

[b] Usual range: maximum may reach 3.0%.

[c] Usual range: maximum may reach 12%.

TABLE XVI-22

COMPOSITION OF SOLID WASTE
RESIDUES FROM POLLUTION TREATMENT PROCESSES
SIC 491

Item: Lime Sludge

Process or Activity: Fossil Fuel Power Plants

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	2	276
Volume, liters	l -wet	1.4	
H_2O content (of wet weight)	%	1	
Combustible	kg	0	
Non-combustible	kg		
Ash content	kg		
Liquid form	kg	1	
Solid form	kg	1	
Energy content	kcal		
Oxygen requirements	kg BOD_5		
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg	Present	
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg		
Non-biodegradable	kg	1	
$CaSO_3 \cdot \frac{1}{2} H_2O$	kg	0.73	
$Ca(OH)_2$	kg	0.11	
$CaSO_4 \cdot 2 H_2O$	kg	0.11	
$CaCO_3$	kg	0.05	

TABLE XVI-23

COMPOSITION OF SOLID WASTE RESIDUES FROM POLLUTION TREATMENT PROCESSES

SIC 491

Item: Limestone Sludge

Process or Activity: Fossil Fuel Power Plants

Solid Waste Residue Characteristics	Units	Units/Kg Dry Residue	Ref. No.
Wet weight	kg	2	276
Volume	l -wet	1.4	
H_2O content (of wet weight)	%	1	
Combustible	kg	0	
Non-combustible	kg		
Ash content	kg		
Liquid form	kg	1	
Solid form	kg	1	
Energy content	kcal		
Oxygen requirements	kg BOD_5		
Valuable metals	kg		
Volatile	kg		
Radioactivity	curies		
Radioactive material	kg		
Toxic chemicals	kg	Present	
Pesticides & chem. warfare	kg		
Pathogens & bio. warfare	kg		
Explosives	kg		
Corrosives	kg		
Liquid hydrocarbons	kg		
Biodegradable	kg		
Non-biodegradable	kg	1	
$CaSO_3 \cdot \frac{1}{2} H_2O$	kg	0.58	
$CaSO_4 \cdot 2 H_2O$	kg	0.09	
$CaCO_3$	kg	0.33	

Desulfurization of fuel is a possible substitute for installation of scrubbers in power plants. Desulfurization would cause different solid waste impacts, but a practical technology will probably not be developed before 1985. The degree of application of saleable product flue gas cleaning devices is also important here. These applications were projected to amount to 20 percent of all capacity controlled beginning in 1975. This estimate, however, is subject to considerable variation, depending in large part on factors such as cost trends as technologies develop, the market for sulfuric acid, the by-product of saleable product processes, and the problems which develop in land disposal of limestone sludge wastes. At the present time these factors may only be estimated in a qualitative way. The overall confidence level for the forecasts in this section is 2, indicating a ± 50 percent possible variation in the data.

Summary

Untreated Discharges. Fossil fuel (coal, gas and oil) and nuclear fission power plants are significant contributors to the National pollution load. The former contributions are significant in terms of residue weight, while the latter are significant in terms of radioactive hazards. Fossil fuel plants release to the air significant quantities of particulates, sulfur and nitrogen oxides, carbon monoxide, carbon dioxide, and hydrocarbons. Of these, only sulfur oxides (principally sulfur dioxide) and non-hydrocarbon particulates are likely to have significant impacts on solid waste generated from pollution control; control of nitrogen dioxide is not likely to be implemented by 1985, while controls for the remaining air pollutants generate minimal solid waste. Of the three fossil fuels, only coal combustion produces significant amounts of particulates. However, coal, oil, and to a lesser extent, gas combustion all prouce sulfur oxide emissions, the exact values of which will vary with the sulfur content of the fuel being burned. Discharges before treatment of particulates from power plants were forecast to increase from 33.6 billion kg in 1971 to 65.8 billion kg in 1985. Similar discharges of sulfur dioxide were forecast to rise at a more rapid rate, from 19.9 billion kg to 42.9 billion kg during the same period.

Wastes generated from nuclear power plants, while their total weight is dwarfed by that of fossil-fuel power plant wastes, are nevertheless important due to their radioactive nature. Most radioactive wastes are produced during the reprocessing and irradiation steps of nuclear power production.

Treatment Methods and Reuse. Air pollution abatement measures for the sulfur oxides generated from fossil-fuel plants consist of the use of low-sulfur fuels and flue gas cleaning systems. These systems may either be throw-away or saleable product processes. The throw-away systems include lime and limestone scrubbing and furnace injection. Settling ponds are typically used to remove solids transferred to water, generating sludges for land disposal. Although some beneficial uses have been proposed for these systems, they are not projected to account for a large percentage of the residues generated through 1985. The saleable product flue gas cleaning systems, which include magnesium oxide systems, the Wellman-Lord Sodium Sulfite Scrubbing system, and catalytic oxidation, generate sulfuric acid which may then be sold. The tables in this section project

XVI 54 3

these systems to account for 20 percent of all flue gas cleaning systems through 1985; considerable variation is possible, however. Where limestone or lime scrubbing systems are utilized, the control of particulates will be accomplished simultaneously with the control of the sulfur oxides. Where saleable product systems are used, the particulates may be removed before the sulfur oxide control system by baghouses and other dry methods or by wet scrubbing systems.

Residues Generated from Pollution Control. Solid waste from pollution control in electric power plants was forecast to increase from 25.6 billion to 135.6 billion kg between 1971 and 1985. Over 10 percent of the weights generated will probably be derived from particulate and sulfur dioxide emission controls in fossil-fuel plants. Figure XVI-10 illustrates some of the trends in fossil-fuel plants underlying this large predicted increase in solid wastes (over 5 times 1971 levels) by 1985. Between 1971 and 1985, uncontrolled emissions of particulates and sulfur dioxide were forecast to increase between 1.5 to 2 times, demand for electricity was forecast to more than double, and the weights of combined sulfur dioxide and particulate emissions that are controlled were forecast to almost triple. The increase in controls is mainly due to better control of sulfur dioxides, as controls for particulate emissions in coal-fuel power plants were virtually completed in 1971.

The weight of solid wastes from nuclear power plants is forecast to increase from 730,000 to 23 million kg between 1971 and 1985; it is assumed that 100 percent controls will be enforced throughout this period.

SECTION XVII

SEWERAGE SYSTEMS
SIC 4952

Introduction.

This sector is an important contributor of solid waste residues disposed to landfills as a result of air and water pollution control. The impact of the 1972 Federal Water Pollution Control Act Amendments on solid waste generation in sewerage systems is significant since the "best practicable" and "best available" treatment processes for 1977 and 1983, respectively, can greatly reduce the quantity of sludges disposed into receiving waters. Secondary treatment produces a greater quantity of residues per liter of wastewater treated than primary or intermediate treatments. Advanced waste treatment will add even more sludges and residues. All tables presented in this Section relate to water pollution control. The only impact of air pollution control laws is to restrict or control the use of incineration, which is forecast to remain at only 10 percent of all sewage sludge disposal through 1985.

Untreated Discharge Factors.

Air Pollutants. Air pollution can result from sludge incineration or anaerobic digester gas combustion. As mentioned above, contribution to air pollution by this sector is minor compared to water pollution. Hence, air pollution control will not be further evaluated in this Section.

Water Pollutants. The following data evaluate sewerage systems insofar as they involve the treatment and disposal of municipal wastes largely of domestic origin. Although many industries discharge through sewer systems, the solid waste implications for these industries have been discussed separately for each. Whether a community and its industries treat their wastes jointly or separately, the industry effluent standards will have to be met. Detailed data is not available for individual industries discharging through sewer systems, and to include them here without subtracting the solid waste residues from the totals of the industrial sector studies would be a double entry.

Table XVII-1 summarizes major water pollutants in domestic wastes. The sludge solids estimates are based on 0.088 kg solids per person per day in the sewage influent. These solids will later create sludge solids of 0.105 kg per person per day when treated by secondary systems because of wasted sludge media.[159] Volume of raw sewage per capita per day is estimated at 378.5 liters; the per-capita annual estimate is 138,000 liters.[159] The estimates apply only for the average quantity of solids reaching municipal sewage treatment plants, although some decomposition in organic matter can occur in the collection system.

For untreated discharges the available data is comprehensive and sewage characteristics are predictable, although innovative practices such as the use of garbage grinders can affect discharge factors. The sludge generation estimates are probably within 10 percent of actual National figures, and can therefore be given a confidence level of 4.

TABLE XVII-1
SOURCES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 4952

Item	Process or Activity	Physical Units	Pollutant	Kg Pollutant (Dry) per Physical Unit[a]	Ref. No.
Raw sewage		per capita/day per capita/year	Solids	0.088 32.11	159
		per capita/day per capita/year	BOD_5	0.076 27.65	174
		per capita/day per capita/year	Total N[b]	0.019 6.94	174
		per capita/day per capita/year	Organic N[b]	0.019 6.94	174
		per capita/day per capita/year	Free NH_3	0.011 4.14	174
		per capita/day per capita/year	Chlorides[b]	0.038 13.91	174

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[a] The yearly figures are equal to the daily figures multiplied by 365.

[b] The original data cited in Reference 174 was expressed in mg/l. The kg /capita/day figures were derived by the ratio of the pollutant concentration in mg/l to the concentration of BOD_5 multiplied by the 0.076 kg /capita/day of BOD_5 from Reference 159. Reference 174 is 1963 data, while Reference 159 is for 1973.

Industry Description and Schematic.

Figure XVII-1 illustrates the basic flows involved in sewerage systems. Two distinct steps can be identified, treatment processes and sludge handling.

Treatment processes are applied to sewage plant influents to remove polluting substances in the wastewater. Various treatment processes with different degrees of sophistication can be employed. Primary systems consist of physical removal processes such as screening, sedimentation and flotation. Secondary processes also include biological and chemical methods such as activated sludge, trickling filters, chemical precipitation, activated carbon, lime, etc. These treatment processes yield both a separate effluent stream and waste residues or sludges.

Sludge handling includes any processing or disposal of the sludge from the treatment process. The techniques may include aerobic or anaerobic digestion of the residues, thickening, dewatering and/or disposal to land or landfills, and the creation of a soil conditioner by-product. Most disposal to the land is done after the sludge is digested, converting much of the organic matter to gases. The remaining sludge may be dried or handled wet and disposed in landfills. In a slurry form, sewage sludge may be two to six percent solids; when dewatered it may be 15 to 25 percent solids which can be disposed in cake or granular form.[176] The ash from sludge incineration is also usually disposed to landfills. Some digested sludge is still discharged to receiving waters or storage ponds, although such practices are declining under increasingly stringent regulations. Stabilized sludges may be used as soil conditioners or have fertilizer additives. This study will be particularly concerned with the disposal of sewage sludge in landfills. Some communities still dispose sludge to receiving waters,but this practice is being strongly discouraged by statutory authorities as a National policy.

Economic Forecasts.

Two components make up the forecasts for sewerage systems listed in Tables XVII-2 and XVII-3. The first, population growth forecasts, are fairly certain, at least through 1985. The second component, the growth in the sewered population in the United States and the degree of treatment applied, is less certain. Based upon the existing laws, one would expect secondary treatment plants by 1983. Recent (1974) delays in Federal construction funding, however, have cast some doubt on the rapid extension of secondary treatment facilities to all sewerage systems. For this reason the forecasts of sewage treatment plant growth through 1985 are a conservative extrapolation of sophisticated treatment facilities. These growth rates show the same strong trends toward increased secondary treatment, but at a slower rate than strict reading of the law would imply. See Figure XVII-2 for past growth trends in sewerage systems.

Table XVII-2 includes some historical data on the breakdown of municipal sewage treatment facilities in the United States based on the data in Figure XVII-2. These data were used in the derivation of Table XVII-2, which lists the numbers of persons

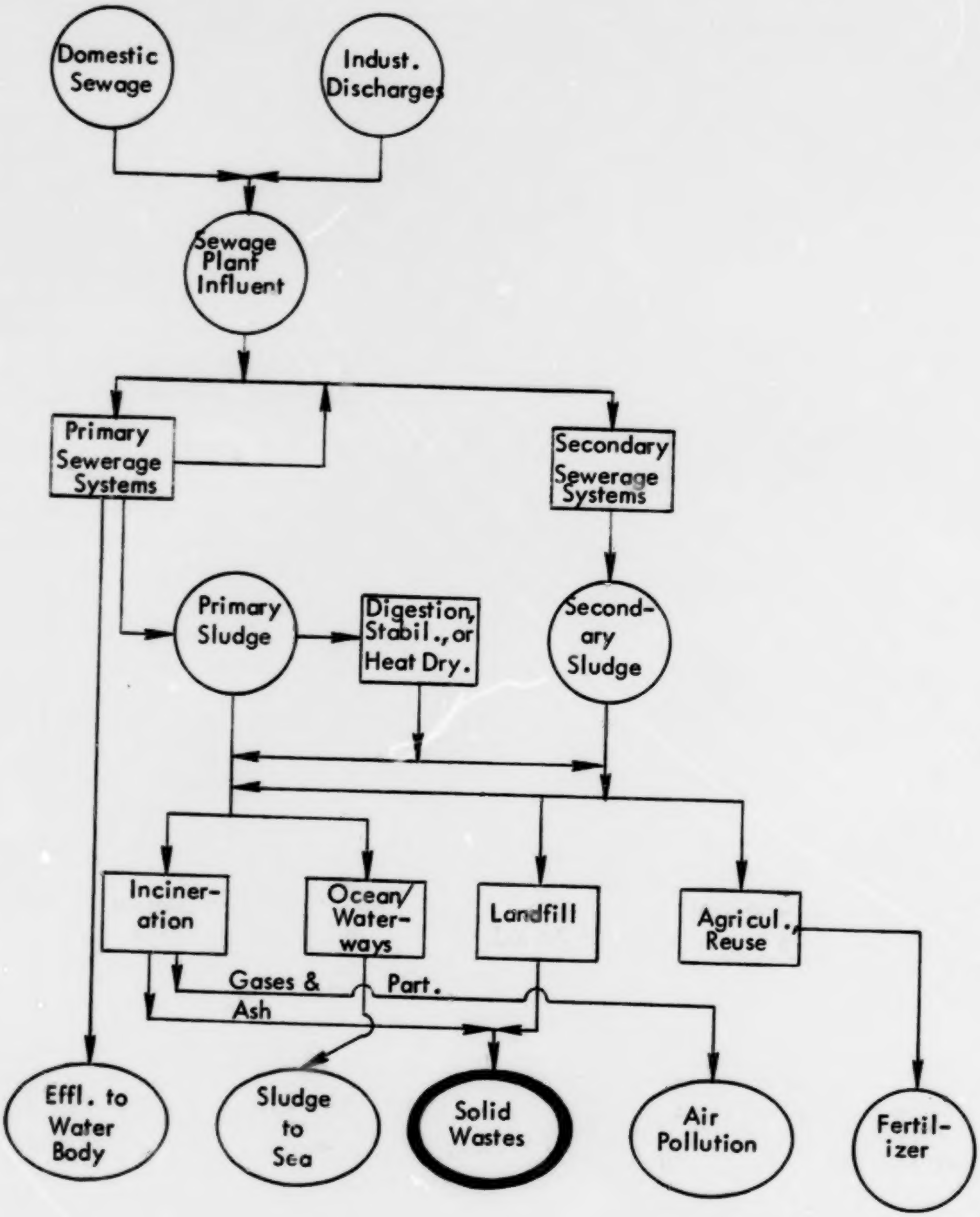
Domestic Sewage
Indust. Discharges
Sewage Plant Influent
Primary Sewerage Systems
Secondary Sewerage Systems
Primary Sludge
Digestion, Stabil., or Heat Dry.
Second-ary Sludge
Inciner-ation
Ocean/ Water-ways
Landfill
Agricul. Reuse
Gases &
Part.
Ash
Effl. to Water Body
Sludge to Sea
Solid Wastes
Air Pollution
Fertil-izer

FIGURE XVII-1

INDUSTRY SCHEMATIC:
SEWERAGE SYSTEMS

TABLE XVII-2
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS
SIC 4952

Item	Process or Activity	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
U.S. population		10^6 persons	1960	179.3					136	1972
			1970	203.2		213.9	224.1	235.7	137	1973
			1973	210.5					137	1973
Non-sewered population		% of pop.	1960	38.9					200	1970
Sewered - no treatment				10.0						
Primary and intermediate treatment				22.0						
Secondary treatment				28.9						
Non-sewered population			1968	32.5					200	1970
Sewered - no treatment				5.0						
Primary and intermediate treatment				22.5						
Secondary treatment				40.0						

TABLE XVII -3
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH[8]
SIC 4952

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
U.S. population		10^6 persons	205.6	a	213.9	136	224.1	136	235.7	136
Non-sewered pop.			61.9	b	57.5	b	45.7	b	31.3	b
Sewered- no treatment			6.4	c	1.3	c	0	c	0	c
Primary and intermediate			46.5	d	48.8	d	51.5	d	54.4	d
Secondary treatment			90.8	e	106.3	e	126.9	e	150.0	e
Total sewered pop.			143.7		156.4		178.4		204.4	
Non-sewered		% of total pop.	30.1	f	26.9	f	20.4	f	13.3	f
Sewered- no treatment			3.1		0.6		0		0	
Primary and intermediate treatment			22.6		22.8		23.0		23.1	
Secondary treatment			44.2		49.7		56.6		63.6	
Treated- total			66.8		72.5		79.6		86.7	

TABLE XVII-3[8] (Cont.)

[a] Derived by a linear interpolation between the 1970 and 1973 figures of Reference 136.

[b] Derived by using a linear extrapolation to 1965 of the −0.8 percent per year decline from 1960 to 1968 in the percent of the population without sewer service in Reference 200.

The formula is:

$$Fy = (B + a\,(Y-1968))\,Py \qquad (1)$$

Where: Fy = forecast millions of persons in this category

B = base year (1968) percent of population in this category)

a = percent/year change in this category

y = forecast year (1971, 1975, 1980, 1985)

Py = population forecast for year y in millions

Since the percent of the population which is sewered but whose sewage receives no treatment would be negative by 1985 the negative amount for that category was subtracted from the non-sewered population. (See (c) below).

[c] Derived by linear extrapolation of the −0.625 percent decline from 1960 to 1968 in the percent of the population which is sewered but receives no treatment using formula (1) in (b) above. Since this percent would be negative by 1980, these negative amounts were subtracted from the forecast non-sewered population.

[d] Derived by extrapolating to 1985 the +0.375 percent change per year in the percent of the population receiving primary and intermediate treatment (from Reference 200) using equation (1) in (b) above.

[e] Derived by extrapolating to 1985 the + 1.3875 percent change per year in the percent of the population receiving secondary treatment (from Reference 200) using equation (1) in (b) above.

[f] Calculated from above data expressed in millions of persons.

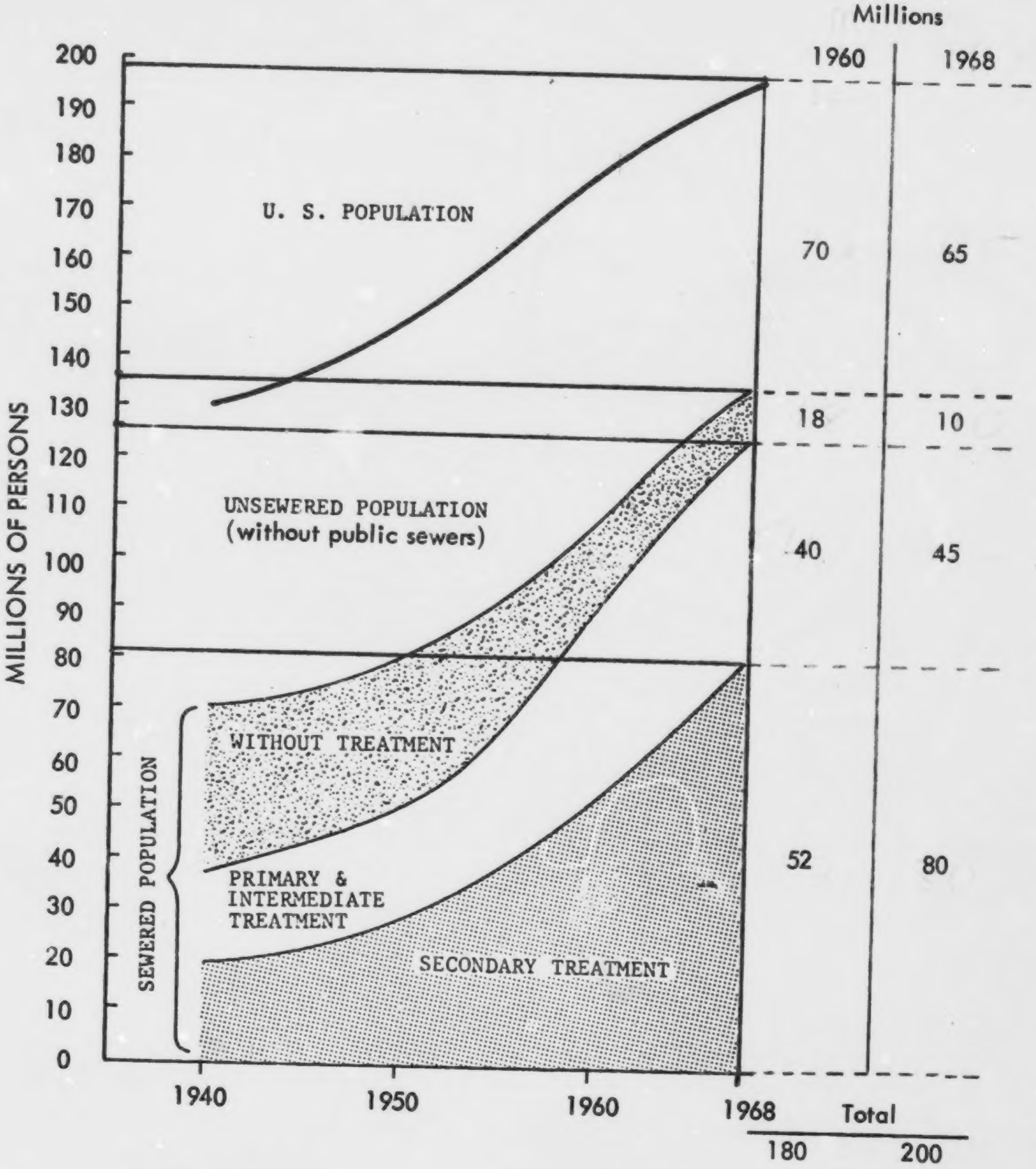

FIGURE XVII-2
GROWTH TRENDS:
SEWERAGE SYSTEMS[63,200]

and the percentage of the population included in each sewage treatment category. The derivations of the data are explained in the footnotes to the table.

The confidence level for the economic forecasts is 4, indicating a ± 10 percent possible variation in the data. Population projections can be expected to be more accurate than the disposal process forecasts.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table XVII-4 indicates the total municipal discharges to sewerage systems. These data were obtained by multiplying the discharge coefficients in Table XVII-1 by the total sewered population from Table XVII-3. Some discharges are also made to septic tanks and cesspools which are not shown here. As shown in Table XVII-3, the percentage of the United States population discharging to septic tanks and cesspools is forecast to decline from a 30.1 percent in 1971 to 13.3 percent in 1985. These discharges, since they go directly to the land, would increase the total sewer discharges by 43 percent in 1971 and by 15 percent in 1985. The final residues from these cesspools and septic tanks when sent to landfills or through sewerage systems will be much less because of the low solids content of the trucked tankage wastes.

Total solids content is the best indicator of total solid waste residue impact of sewerage systems and will be used in the following tables. The composition of these residues is also important and will be briefly analyzed at the end of this Section.

As previously indicated, industries discharging to municipal sewerage systems are considered in separate Sections of this report. Table XVII-5 is presented to characterize these industrial discharges and to show their relative volumes. The nature, extent and pretreatment provided or kinds of solids discharged is not available. Table XVII-5 indicates that industrial discharges play an important role in total discharges to sewerage systems, and they may contribute significant quantities of heavy metals and other toxic materials which either disrupt the functioning of the sewerage treatment processes or create final disposal problems. Discharge data may be given a confidence level of 4, indicating a possible 10 percent variation.

Likely Pollution Treatment Processes.

No public approval has been found for present and future large scale disposal for undigested or raw sewage sludges. The data presented are, therefore, only projections of current practices. Table XVII-6 presents the major treatment and disposal alternatives for sewerage systems. Only two treatment categories are given: (1) primary, and (2) secondary. The available data are not sufficiently detailed to justify further refinement to include limited future tertiary treatment.

The sludge residue volumes from primary (physical) treatment are largely a function of the treatment removal efficiency. In the case of secondary treatment, the residues vary depending on the process. Activated sludge plants produce residue volumes prior

TABLE XVII-4
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC 4952

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Solids to sewers		159	4,614	5,022	5,728	6,563
BOD_5 to sewers		174	3,973	4,324	4,932	5,620
Total N to sewers		174	1,001	1,089	1,243	1,424
Chlorides to sewers		174	1,998	2,175	2,480	2,843

TABLE XVII-5

BOD$_5$ AND SUSPENDED SOLIDS IN INDUSTRIAL WASTEWATER DISCHARGES, 1969

Industry	Percent of Sectors Discharges to Public Sewers	Discharges (10^6 kg/year, dry weight) Wt Total BOD$_5$ 102	SS 102	Wt to Public Sewers BOD$_5$	SS
Food and kindred products	23.0	57	161	13	37
Textile mill products	15.9	45	9	7.2	1.4
Paper and allied products	4.4	431	367	19	16.1
Chemicals and allied products	2.3	222	246	5.1	5.7
Petroleum products	1.9	76	130	1.5	2.5
Rubber and plastics products	32.7	0.8	2.7	0.3	0.9
Primary metals products	4.3	3.6	100	.2	4.3
Total		835.4	1015.7	46.3	67.9

TABLE XVII-6

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC 4952

Item	Process or Activity	Pollutant Treated	Disposal Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed	Cost Range: $ per Physical Unit	Ref. No.
Sewerage systems	Primary treatment	Solids	Landfills, not digested	65	1.0	19-29	175
			Landfills, digested		0.5	31-50	176
			Incineration		0.3	22-82	176,238
			Ocean/waterways		1.0		172
			Agricultural, other reuse		1.0	Sale-15 Cost-60	55
	Secondary treatment	Solids	Landfills, not digested	85-95	1.2	19-29	11,175
			Landfills, digested		0.6	31-50	176,238
			Incineration		0.3	22-82	176,238
			Ocean or receiving waters		1.2		172
			Agricultural, other reuse		1.2	Sale-15 Cost-60	55

to digestion approximately equal to the suspended solids removed plus 30 percent of the BOD_5 removed.[176] Trickling filter plants typically add to the sludge weights equal to 10 percent of the suspended solids removed.[176] For this reason, in Table XVII-6, sludge produced per kilogram of solids removed was estimated as 1.2 kg (dry weight) for secondary treatments vs. 1.0 kg (dry weight) for primary treatments. The exact treatment efficiencies vary but are considerably higher for secondary than for primary treatments (85-95 percent vs. 65 percent).[11,175] For these reasons, the greater application of secondary treatments will generate more sewage sludges nationally, in addition to the increases caused by the higher percentages of the population that will be served by future sewerage system expansion. Secondary chemical and tertiary treatment processes are even greater generators of waste residues (sludges) than biochemical methods; however, because of greater operating costs and disposal problems, secondary chemical and tertiary treatment is projected for the future.

Table XVII-6 also lists the main alternative disposal techniques for sewage sludge. Although all alternatives are not listed, their major impacts upon solid waste residue generation can be determined from the categories shown. If sludge is digested, approximately 52 percent reduction in mass is obtained by conversion of organic matter to gases.[238] Other sources cite 33 to 42 percent reduction in mass by digestion,[176] but a recent comprehensive study by the EPA indicates 52 percent and is considered an improved estimate. A factor of 0.5 kilograms of digested sludge per kilogram of raw sludge was thus used in Table XVII-6.

If the sludge is incinerated before disposal, the mass is reduced by 75 percent. This latter method accounts for approximately 10 percent of all sludge disposal. When sludge is discharged to the ocean or other receiving waters, it is usually first digested. Agricultural spreading, composting, etc. directly reduces solid waste residues for landfills, and the weight of these residues is not important for this study. The ratio of residues to the dry weight of solids removed as shown in Table XVII-6 is the product of the ratios for the treatment process and for the disposal technique. These figures are used later in Tables XVII-9 through XVII-12 to calculate total solid waste residues from water pollution control in sewerage systems.

The cost data for treatment and disposal are approximate, depending on local factors such as the process and local sewerage systems characteristics. If no agricultural land is near, agricultural reuse would, of course, be expensive; distance to acceptable landfill sites is also a major factor in transport and disposal costs.

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

Table XVII-7 lists the estimated percentages of reuse for residues from alternative sewage sludge processing techniques. These percentages are accurate for each processing technique, as each particular method is designed for a particular purpose. The breakdown of these disposal techniques and the resultant overall percent of reuse for sewage sludge is, however, fairly uncertain. Reuse data for sewage sludges may be given a confidence level of 4, indicating a possible 10 percent variation in the data.

TABLE XVII-7
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES[55,159,172]
SIC 4952

Item and Pollutant	Treatment/Disposal Process	% Reuse	Description/Disposal of Residue
Sewerage systems - liquid sludge	Primary treatment		
	To landfill, not digested	0	Raw sludge
	To landfills, digested	0	Metals, other inorganics and residual organics
	Incineration	0	Ash to landfills
	Ocean/waterways	0	Raw sludge
	Agricultural, other reuse	100	Depends on process: composting, lime stabilization, etc.
	Secondary treatment		
	To landfills, not digested	0	Raw sludge
	To landfills, digested	0	Metals, other inorganics and residual organics
	Incineration	0	Ash to landfills
	Ocean /waterways	0	Raw sludge
	Agricultural, other reuse	100	Depends on process: composting, lime stabilization, etc.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Table XVII-8 forecasts the relative use of various sewage sludge disposal methods for 1971, 1975, 1980, and 1985. The key assumptions made in constructing Table XVII-8 relate to the predicted use of the various sludge disposal techniques. Currently, approximately 10 percent of sewage sludge is incinerated,[172] and another 15 percent is discharged to waterways.[172] No firm data exist for agricultural reuse of sludge,[172] but it is not a very large proportion. For present purposes, it is estimated that 10 percent of the sludge is reused in agricultural or other applications. Thus, approximately 65 percent is currently disposed to landfills; of this amount approximately 95 percent is digested before disposal. Waterways discharge is being restricted by law and is predicted to cease by 1975. The amounts previously discharged to the ocean or waterways were added to the landfill totals.

Tables XVII-9 through XVII-12 give final estimates of solid waste residues from water pollution control in sewerage systems destined for landfills in 1971, 1975, 1980, and 1985, respectively. Total solids received by sewerage systems with either primary or secondary treatment are forecast to be: 1971 - 4,471 x 10^6 kg, 1975 - 4,992 x 10^6 kg, 1980 - 5,728 x 10^6 kg, and 1985 - 6,563 x 10^6 kg. The percentages of projected use of various disposal processes in Tables XVII-9 through XVII-12 were derived from both the forecasts in Table XVII-8 and appropriate population projections in Table XVII-3.

The amount of solid waste residues destined for landfills is forecast to increase by 85 percent from 1,528 million kilograms in 1971 to 2,820 million kilograms in 1985. If comprehensive secondary treatment were used for the sewered population in 1985, and if all raw sludge were sent to landfills without digestion, the total would be 7,866 million kilograms. In addition, if the 13.3 percent forecast for the non-sewered population were included in secondary treatment, the total sludge sent to landfills would be 9,072 million kilograms. The explanation for the lower estimate lies in the predicted use of digesters (95 percent of all solids sent to landfills) in the production of solid waste residues. Also, the forecast of 23.1 percent primary systems in 1985 reduces the estimate. Incineration, where it is used, reduces the total weight disposed to landfills by 90 percent but is a minor factor in the forecast, as is agricultural reuse of sewage sludge. Incinerated sewage sludge still contains extensive ash (± 50%) by dry weight.

Even though the assumptions made above restrict the accuracy of the estimates, the final forecasts are probably within ± 50 percent and can then be given a confidence level of 2. Most raw sludge is digested; incineration and agricultural spreading will probably not become major factors in the near future; in some areas ocean or waterway discharge is already being abandoned.

TABLE XVII-8

FORECAST SEWAGE SLUDGE DISPOSAL METHODS THROUGH 1985

Sludge Disposal Method	Percent of Total Raw Sewage Sludge for: 1971	1975	1980	1985
To landfills, not digested	3	4	4	4
To landfills, digested	62	66	71	76
Incineration	10	10	10	10
Ocean/waterways	15	10	5	0
Agricultural or other reuse	10	10	10	10
Totals	100	100	100	100

TABLE XVII-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC 4952

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Solids:								
Sewerage systems	Primary treatment	To landfills, not digested	1.0	50	65	30	100	30
		To landfills, digested	21.0	470	65	310	100	310
		Incineration	3.4	50	65	30	100	30
		Ocean/waterways	5.1	240	65	150	0	0
		Agricultural, other reuse	3.4	1,150	65	100	0	0
		Total	33.9	960	64	620	60	370
	Primary & secondary treatment	To landfills, not digested	2.0	110	90	100	100	100
		To landfills, digested	41.0	1,100	90	990	100	990
		Incineration	6.6	90	90	80	100	80
		Ocean/waterways	9.9	530	90	480	n.a.	0[a]
		Agricultural, other reuse	6.6	350	90	320	0	0
		Total	66.1	2,180	90	1,970	54	1,170
Total Residues from Water Pollution Control			100	3,140	82	2,590	56	1,540

---

[a] Although some solids may be present in sludge dumped to the ocean, these are not considered as solid waste residues as defined elsewhere in this report.

TABLE XVII-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC 4952

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Solids:								
Sewerage systems	Primary treatment	To landfills, not digested	1.2	60	65	40	100	40
		To landfills, digested	20.8	520	65	340	100	340
		Incineration	3.1	50	65	30	100	30
		Ocean/waterways	3.1	150	65	100	0	0
		Agricultural, other reuse	3.1	150	65	100	0	0
		Total	31.3	930	66	610	67	410
	Primary & secondary treatment	To landfills, not digested	2.8	170	90	150	100	150
		To landfills, digested	45.2	1,350	90	1,220	100	1,220
		Incineration	6.9	100	90	90	100	90
		Ocean/waterways	6.9	410	90	370	n.a.	0[a]
		Agricultural, other reuse	6.9	410	90	370	0	0
		Total	68.7	2,440	82	2,200	66	1,460
Total Residues from Water Pollution Control			100	3,370	83	2,810	66	1,870

---

[a] Although some solids may be present in sludge dumped to the ocean, these are not considered as solid waste residues as defined elsewhere in this report.

TABLE XVII-11
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC 4952

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Solids:								
Sewerage systems	Primary treatment	To landfills, not digested	1.2	70	65	40	100	40
		To landfills, digested	20.5	590	65	380	100	380
		Incineration	2.9	50	65	30	100	30
		Ocean/waterways	1.4	80	65	50	100	0
		Agricultural, other reuse	2.9	170	65	110	100	0
		Total	28.9	960	64	610	74	450
	Primary & secondary treatment	To landfills, not digested	2.8	190	90	170	100	170
		To landfills, digested	50.5	1,730	90	1,560	100	1,560
		Incineration	7.1	120	90	110	100	110
		Ocean/waterways	3.6	450	90	410	n.a.	0[a]
		Agricultural, other reuse	7.1	490	90	440	0	0
		Total	71.1	2,980	90	2,690	68	1,840
Total Residues from Water Pollution Control			100	3,940	84	3,300	69	2,290

---

[a] Although some solids may be present in sludge dumped to the ocean, these are not considered as solid waste residues as defined elsewhere in this report.

TABLE XVII-12
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC 4952

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Solids:								
Sewerage systems	Primary treatment	To landfills, not digested	1.1	70	65	50	100	50
		To landfills, digested	20.2	660	65	430	100	430
		Incineration	2.7	50	65	30	100	30
		Ocean/waterways	0	0	65	0	0	0
		Agricultural, other reuse	2.7	180	65	120	0	0
		Total	26.7	960	66	630	81	510
	Primary & secondary treatment	To landfills, not digested	2.9	230	90	210	100	210
		To landfills, digested	55.8	2,200	90	1,980	100	1,980
		Incineration	7.3	140	90	130	100	130
		Ocean/waterways	0	0	90	0	n.a.	0[a]
		Agricultural, other reuse	7.3	580	90	520	0	0
		Total	73.3	3,150	90	2,840	82	2,320
Total Residues from Water Pollution Control			100	4,110	84	3,470	82	2,830

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[a] Although some solids may be present in sludge dumped to the ocean, these are not considered as solid waste residues as defined elsewhere in this report.

Composition of Solid Waste Residues. To specify completely the nature of the solid waste residues generated by sewage treatment systems a detailed knowledge of the particular treatment processes and disposal techniques used in all large systems would be necessary. The data in Tables XVII-13 through XVII-15 represent "typical" composites which may vary greatly from system to system.

The composition of sludges disposed to landfills is primarily a function of the treatment methods utilized. Where industries discharge to the sewers, this will also affect sludge composition. Table XVII-13 expresses the major components of sewage sludges as a function of the treatment processes. The categories listed are the most important, although many variations can exist. Large numbers of fecal bacteria are present in raw sewage sludges, but most of these bacteria are removed by digestion and storage. Fecal bacteria counts in raw sludge may be substantially reduced either by digestion or lime stabilization to a pH of 12.[55] Sludge may also be pasteurized to reduce bacteria counts without digestion.[55]

Table XVII-14 expresses the elements present in sewage sludges as a function of the treatment method. Heavy metals are clearly more concentrated in digested than in raw sludges. The organic material in sludges is substantially reduced by digestion, thus concentrating the heavy metals. Some heavy metals are present in surface runoff discharged to sewerage systems. The concentration of these metals is very much influenced by the degree of urbanization of the runoff area. Table XVII-15 illustrates some heavy metal concentrations for urbanized areas.

When sewage sludges are incinerated, the resulting ash contains oxides of silicon, aluminum, iron, calcium, and phosphorus plus trace materials. The ashes are moderately basic and have a water solubility of under about 2.0 weight percent when ash is leached with 20 times its mass of water.[238] The silicon, aluminum, iron and phosphorus and most of the calcium are probably fixed in a highly insoluble form. The sodium, potassium, and some of the calcium could probably be leached away as hydroxides. Although most metals are fixed in incinerator ash in higher concentrations than in sewage sludge, some like mercury are lost to the stack gases. Pesticides and PCB are not detectable in stack gases and are presumed destroyed, although specific evidence of this is lacking.[238]

Factors Affecting Quality of the Data.

Although the available data on sewage treatment process trends and growths in the sewered population seem fairly accurate, data regarding the degree of use of alternative sludge handling and disposal techniques are much more uncertain. Ocean and waterways dumping is known to be declining; data regarding the growth of incineration and agricultural spreading of sewage sludges is limited. In order to improve the estimates contained in this study, detailed surveys of sludge handling techniques throughout the United States will be necessary. The overall confidence level for the solid waste impact of water pollution control in sewerage systems is 2, indicating a possible 50 percent variation in the forecasts.

TABLE XVII-13
MAJOR COMPONENTS OF SEWAGE SLUDGES[238]
SIC 4952

Percent of Total Dry Weight of Sludge

	Type of Sludge				
Constituent	Raw Primary[a]	Digested[b]	Raw Secondary[c]	Filter Cake Raw	Filter Cake Digested
Volatile matter	60-80	45-60	62-75	55-75	40-60
Ash	20-40	40-45	25-38	25-45	40-60
Insoluble Ash	17-35	35-50	22-30	15-30	30-45
Greases and fats	7-35	3-17	5-12	5-30	2-15
Protein	22-28	16-21	32-41	20-25	14-30
NH_4NO_3	1-3.5	1-4	4-7	1.3	1.3-1.6
P_2O_5	1-1.5	0.5-3.7	3-4	1.4	0.5-3.5
K_2O		0-4	0.86		
SiO_2		20-22	12		
Fe		5.4	7.1		
Cellulose	10-13	10-13	7.8	8-10	8-12

[a] Undigested sewage sludge from primary treatment processes.

[b] Digested primary and secondary sewage sludges.

[c] Undigested sewage sludge from secondary treatment processes.

TABLE XVII-14
ELEMENTS CONTAINED IN SEWAGE SLUDGES[238]
SIC 4952

Element	Type of Sludge (mg/g of dried sludge)		
	Raw Primary[a] Sludge	Raw Secondary[b] Sludge	Digested[c] Sludge
Aluminum	5.1	10.0	17.9
Antimony	n.a.[d]	n.a.	0.9
Arsenic	< 1.2	1.2	n.a.
Barium	2.2	1.2	1.4
Beryllium	0.0025	0.0035	0.0025
Boron	0.10	0.070	0.046
Cadmium	< 0.19	0.35	0.26
Calcium	n.a.	13.0	33.5
Chromium	2.0	4.3	2.3
Cobalt	0.22	0.002	n.a.
Copper	2.0	1.1	1.6
Gallium	0.06	0.05	0.05
Iron	16.1	40.5	30.6
Lead	1.0	1.5	1.9
Magnesium	10.6	7.0	7.5
Manganese	0.78	0.31	0.98
Mercury	0.005	0.02	n.a.
Molybdenum	0.36	0.20	0.25
Nickel	0.52	0.38	0.38
Phosphorous	3.8	19.9	12.8
Potassium	n.a.	4.2	2.8
Silicon	n.a.	40.0	162
Silver	0.24	0.15	0.20
Sodium	4.0	4.4	6.2
Strontium	0.13	0.16	0.26
Sulfur	n.a.	10.1	12.3
Tin	0.95	0.50	0.60
Titanium	14.8	11.8	14.2
Vanadium	2.1	0.7	5.2
Zinc	6.9	3.3	4.0
Zirconium	1.7	10.0	2.0

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[a] Undigested sludge from primary treatment processes.

[b] Undigested sludge from secondary treatment processes.

[c] Digested primary and secondary sewage sludges.

[d] Not available.

TABLE XVII-15

HEAVY METALS PRESENT IN SUSPENDED SILTS IN RIVER RUNOFFS[233]

Metal	mg Metal/kg Suspended Silt	
	Natural Area	Urbanized Area
Manganese	200	400
Cadmium	100	800
Chromium	500	2,000
Copper	500	2,000
Nickel	600	2,000-5,000
Zinc	400	3,000-5,000
Lead	1,000	3,000-8,000
Iron	30,000	30,000

Summary.

Untreated Discharges. The main source of pollutants discharged to the sewerage systems evaluated in this Section is municipal influent from the publicly sewered population. Significant pollutants contained in this influent are solids, BOD_5, total nitrogen, and chlorides. Uncontrolled discharges for these pollutants in 1985 were forecast to be 6.6, 5.6, 1.4, and 2.8 billion kg, respectively.

Treatment Processes and Reuse. The impact of treatment methods on solid waste will greatly depend on subsequent disposal practices. Secondary treatments will produce more solid waste residues than primary treatments. Disposal methods that will have a significant impact on solid waste residues are primarily landfilling, with or without prior digestion, and to a lesser extent, incineration. The reuse potential for sewage sludge is great; agricultural or other land treatment is often feasible, depending primarily on economic and technical acceptance factors; it was forecast to remain stable through 1985.

Residues Generated from Pollution Control: Types and Amounts. Solid residues generated from water pollution control and subsequent disposal were forecast to increase to 2.8 billion kg in 1985, up 85 percent from 1.5 billion kg in 1971. The main factors responsible for this increase are the growth in publicly sewered population and the increasing use of secondary treatment between 1971 and 1985. The compostion of the residues will be a function of the types of treatments applied to the sludge. Bacteria counts will be high in raw primary sludge, and digested sludges can be expected to have smaller percentages of pathogens, volatile matter, greases and fats, and protein, and higher percentages of ash and silica than either raw primary or secondary sludges. Sludge from urbanized areas can be expected to have a much higher concentration of heavy metals than that from rural areas, and thus be less suitable for agricultural or other reuse.

SECTION XVIII
REMAINING INDUSTRIAL SECTORS

Introduction.

This Section will evalute the solid waste impact of pollution control activities in all other significant industrial sectors not previously discussed. The sectors to be considered are the following:

SIC 08	Forestry
SIC 205-209	Miscellaneous Food and Kindred Products
SIC 22	Textile Mill Products
SIC 24	Lumber and Wood Products, except Furniture
SIC 295	Paving and Roofing Materials
SIC 30	Rubber and Miscellaneous Plastic Products
SIC 31	Leather and Leather Products
SIC 327	Concrete, Gypsum and Plaster Products
SIC 335	Nonferrous Rolling and Drawing
SIC 336	Nonferrous Foundries (Castings)
SIC 37	Transportation Equipment
SIC 40	Railroad Transportation
SIC 42	Motor Freight Transportation and Warehousing
SIC 45	Transportation by Air
SIC 4953	Refuse Systems
SIC 5541	Automobile Transportation (as fabricated by Service Station Sales)

These sectors were studied in less detail than previous sectors. In the interests of brevity, untreated discharge factors and industry descriptions for these sectors are not included in this Section. The untreated discharges used for forecasting solid waste impacts are tabulated in Appendices A and B for the year 1971.

Economic Forecasts.

Growth rates obtained from Predicasts[68] were used to establish production forecasts for the industrial sectors studied in this Section. Table XVIII-1 presents production estimates for 1971 and forecasts for 1975 through 1985; footnotes explain special assumptions or procedure deviations used in specific cases. The confidence level for the data in this Section is 3, indicating a 25 percent possible variation in the data.

Discharge Inventory of Pollutants Capable of Producing Solid Waste.

Table XVIII-2 lists uncontrolled air and water pollutant discharges from the sectors under consideration. Air pollutants, primarily particulates, are by weight the most significant

TABLE XVIII-1
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC MISCELLANEOUS

Item	Process or Activity	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Forestry[a]										
Beverages		% of 1967	131.6	68	161	68	191	68	222	68
Miscellaneous		% of 1967	118.4	68	120	68	132	68	146	68
Textile mill prod.		% of 1967	108.6	68	132	68	154	68	177	68
Lumber & wood prod.		% of 1967	113.9	68	134	68	155	68	178	68
Paving & roofing mtls.		10^9 $ new construction	109.4	68	151	68	211	68	272.5	68
Rubber & misc. plastic prod.		% of 1967	126	68	176	68	235	68	308	68
Concrete, gypsum & plaster prod.		% of 1967	108.2	68	130	68	150	68	172	68
Nonferrous foundries		% of 1967	111	68	150	68	180	68	215	68
Railroad transportation		10^9 ton-miles	1,937	68	2,350	68	2,850	68	3,400	68
Trucking & warehousing		10^6 truck & bus registration	20.2	68	25.0	68	29.5	68	34.5	68
Transport. by air		10^3 employes	343	68	410	68	490	68	550	68
Automobile transport.		Motor veh. 10^9 miles	1,186	68	1,350	68	1,610	68	1,875	68
Solid waste disposal	Incineration	10^6 kkg burned	40	b	47	b	177	b	204	b
	Open burning	10^6 kkg burned	176	b	88	b	0	b	0	b
	Land disposal	10^6 kkg	183	b	333	b	377	b	436	b

TABLE XVIII-1 (Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
SIC MISCELLANEOUS

[a] No data.

[b] Data from the Economics of Clean Air[89] were used to calculate, by linear interpolation and extrapolation, the total amounts of solid waste disposal for the period 1971 through 1985, and the 1971 distribution into incinceration (10 percent of the total), open burning (44 percent of the total), and land disposal (46 percent of the total). Open burning is assumed to decline from its 1971 level, and to be completely banned by 1980.[89]

TABLE XVIII-2
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC MISCELLANEOUS

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
AIR POLLUTANTS						
Particulates:		See Appendix C				
	Forestry		249	249	249	249
	Misc. food		1	1	1	1
	Textile mill prod.		92	112	129	150
	Lumber & wood prod.		15	18	21	23
	Paving & roofing mtls.		4,400	6,072	8,492	10,956
	Rubber & misc. plastic prod.		5	7	9	12
	Concrete, gypsum & plaster prod.		3,582	4,301	4,964	5,695
	Nonferrous foundries		30	39	49	58
	Railroad transp.		44	53	65	77
	Trucking & warehousing		267	331	390	457
	Transp. by air		21	25	30	34
	Automobile transp.		342	388	463	539

TABLE XVIII-2 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC MISCELLANEOUS

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Particulates: (Cont.)						
	Solid waste disposal: incineration		280	329	1,239	1,428
	Total		9,370	11,840	16,090	19,700
SO_X		See Appendix C				
	Railroad transp.		98	119	144	172
	Trucking & warehousing		290	360	423	496
	Transp. by air		10	12	14	16
	Automobile transp.		2,516	2,802	3,407	3,968
	Total		2,914	3,293	3,988	4,652

TABLE XVIII-2 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC MISCELLANEOUS

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
WATER POLLUTANTS						
BOD$_5$:		See Appendix C				
	Beverages		445	543	645	752
	Misc. food products		63	64	70	77
	Textile mill products		348	423	493	567
	Leather & leather prod.		70	68	66	64
	Nonferrous rolling & drawing		3	4	5	6
	Transportation equipment		16	20	25	29
	Total		945	1,122	1,304	1,495
Suspended Solids:		See Appendix C				
	Beverages		11	13	16	19
	Misc. food products		37	37	41	45
	Textile mill products		262	318	372	427
	Leather & leather prod.		98	96	94	92

TABLE XVIII-2 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE
SIC MISCELLANEOUS

Pollutant	Process or Activity	Ref. for Discharge Factor	10^6 Kg Pollutant Discharged			
			1971	1975	1980	1985
Suspended Solids: (Cont.)	Nonferrous rolling & drawing		22	30	37	43
	Transportation equipment		18	23	28	33
	Total		448	517	588	659

contributions to environmental pollution from these miscellaneous industries. Most of the particulates discharged originate from the production of paving and roofing materials; concrete, gypsum, and plaster products; and from solid waste disposal. Sulfur oxide discharges, although significant by weight, will have minimal impact on solid wastes from pollution control since no controls are expected in the major discharging sectors (such as automobile emissions) by 1985. Hence, sulfur oxides are not further evaluated in this Section.

In general, the quantities of pollutants discharged were calculated by multiplying the 1971 level of discharges by the growth factors established for each sector for the years 1975, 1980 and 1985. Important exceptions from this approach are briefly discussed below.

Forestry. Forest fire particulate emissions are not considered to depend significantly on economic growth and no control systems exist capable of producing significant quantities of solid wastes. Thus, it is assumed that particulate discharges will remain constant through 1985.

Refuse Systems. Particulate generation from solid waste disposal systems was calculated using the economic forecasts and an emission factor of 7 kg of particulates per kkg of refuse burned.[169] This rate, essentially due to open burning, is approximately the same as that given for municipal (settling chamber plus water spray) and industrial and commercial (single chamber) incinerations with minimal controls.[169] Controls for 1977 require open burning be replaced in about equal proportions by land disposal and controlled incineration. This would increase the amount incinerated from 10 to 32 percent of the total solid waste produced.

Leather and Leather Products. BOD$_5$ generated in this sector was obtained directly from *The Cost of Clean Water*[349] by linear interpolation and extrapolation. Although the BOD$_5$ per kkg of hides was approximately the same in *The Cost of Clean Water*[349] and in the suggested Effluent guidelines,[63] the suspended solids per kkg of hides were half as much in the latter, more recent, source. (Pollutant-output ratios are not listed in the Effluent guidelines, but are calculated by weighting the categories therein by their relative contributions.) Therefore, the yearly SS output was calculated by dividing the SS output in *The Cost of Clean Water*[349] by one-half.

Miscellaneous Food Products. BOD$_5$ and suspended solids discharges are mainly from sugar beet processing, raw sugar refining, and fish processing. BOD$_5$ contributions from sugar beet processing are estimated at 3.2×10^6 kg (20 kg BOD$_5$/kkg $\times$ 160 $\times$ 10^3 kkg).[340] A similar derivation was used to estimate raw sugar refining discharges at 13×10^6 kg.[348] Lastly, fish processing contributions were estimated at 47×10^6 kg.[11] The total BOD$_5$ discharge for these three subsectors was therefore estimated at 63×10^6 kg for 1971. For suspended solids discharges, 12×10^6 kg are contributed by sugar beet processing (75 kg SS/kkg $\times$ 160 $\times$ 10^3 kkg),[340] 19×10^6 kg by raw sugar cane refining,[348] and 6×10^6 kg from fish processing,[11] totaling 37×10^6 kg suspended solids discharged in 1971. The confidence level for the information on Table XVIII-2 is 3, indicating a 25 percent possible variation in the data.

Likely Pollution Treatment Processes.

The most likely pollution treatment processes for controlling particulates, BOD_5 and suspended solids are listed in Table XVIII-3. The lumber and wood products sector has been omitted, since control is merely a conversion to other methods of waste disposal. Forestry and all transportation sectors either have no controls or the controls are at the developmental stage and are not likely to be implented by 1985. The confidence level in this Section is 2, indicating a 50 percent possible variation in the data.

Reuse Potential for Solid Waste Residues Produced by Pollution Treatment Processes.

The reuse percentages for solid waste residues are estimated in Table XVIII-4; these should be considered only fair approximations. For example, lint from textile mill products is potentially saleable as a low valued by-product,[91] but there are no quantitative data available. Similarly, there are no data available on the amount of fly-ash from incinerators reused for paving or brick manufacture; the amount is estimated to be less than 10 percent, and probably close to zero.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

Tables XVIII-5 through XVIII-8 forecast solid residues from pollution control in these sectors under consideration for 1971, 1975, 1980, and 1985. The sectors with the most impact on solid waste generation are paving and roofing materials, refuse systems, textile mill products, and leather and leather products. The 4 percent of the particulates that are captured by the venturi scrubber treatment process in the manufacture of paving and roofing material produces about 200×10^6 kg of residues. The percentage contribution from each treatment for paving and roofing materials production was calculated on the basis of an average output of a small plant, being 45 kg/day; that of a large plant, 272 kg/day; and the average plant, 136 kg/day.[89] Hence, approximately 60 percent of the output is due to large plants, and 40 percent to small plants. Owing to the various data inadequacies, the final estimates for solid waste residue derived from the industries in this Section are given a confidence level of 2, indicating a 50 percent possible variance in the data.

Composition of Solid Waste Residues from Pollution Treatment Processes.

The final solid waste residues remaining from pollution treatments are of four types. The first, the lumber and wood residues that were being open-burned (but will be composted, landfilled, or incinerated in the future), are the original materials themselves, and are not described further. The second, the particulates captured dry and disposed of dry, have a composition similar to that of incinerator fly ash.[156,347] The third, the particulates captured by wet scrubbers, have a composition, when dry, similar to that of the corresponding original dry particulates, minus a few soluble salts (e.g., Na, K, Mg salts), plus lime, alum or polyelectrolyte coagulants if present. The fourth residue type is the sludges generated in wastewater treatment. These have not been completely described in the available literature and are quite different from each other. The residues

TABLE XVIII-3

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE SIC MISCELLANEOUS

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed[a]	Cost Range: $ per Physical Unit	Ref. No.
Misc. food prod.		Particulates	Cyclone	70	1		11
Textile mill prod.			Lint filter	99	1		91
Paving & roofing materials			Cyclones	95	1		3,89,121, 169
			Cyclones & venturi scrubber	99	1		3,169
			Cyclones & fabric filters	99+	1		89
Rubber & misc. plastic prod.			Baghouse	100	1		254
Concrete, qypsum & plaster prod.			Baghouse	99.5	1		169
Nonferrous foundries			Baghouse	94-98			91,491
All transportation			Misc.		0		89
Solid waste disposal			Scrubbers	95	1		347
			Elect. precip.	95	1		347
Beverages		Suspended solids BOD_5	Sedimentation & biological stabilization	To 100	1		21
Misc. food prod.		Suspended solids BOD_5	Sedimentation & biological stabilization	To 100	1		21

TABLE XVIII-3 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC: MISCELLANEOUS

Item	Process or Activity	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg (Dry) Removed [a]	Cost Range: $ per Physical Unit	Ref. No.
Textile mill prod.		Suspended solids BOD_5	Sedimentation &/or coagulation & activated sludge &/or trickling filter	80–100	1		240
Leather & leather prodc.		Suspended solids BOD_5	Clarification, activated sludge & filtration	97.7–99.8	1.1[b]		63
Nonferrous rolling & drawing		Suspended solids BOD_5	Sedimentation	69–96	1		349
Transportation equip.		Suspended solids BOD_5	Neutralization, coagulation & sedimentation		n.d.		21

TABLE XVIII-3 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES CAPABLE OF GENERATING SOLID WASTE

SIC: MISCELLANEOUS

[a] Based on suspended solids effluent limitations as suggested in the Effluent Guidelines Report for the leather industry,[63] best practicable technology (1977) has an efficiency of 97.7 percent and best available technology (1983) has an efficiency of 99.8 percent. These efficiences were determined by weighting suspended solids discharges from six production categories by the respective production percentages.

[b] Total alkalinity as $CaCO_3$ is 77.9 kg/kkg; and alkalinity as $Ca(OH)_2$ is 57.6 kg/kkg. Of the 125.6 kg SS/kkg hide, up to about 57.6 kg consists of suspended lime. When lime is naturally of artificially carbonated, the weight increases by a factor of (100/74) producing 1.2 kg of residue/kkg hide. The same range 1-1.2, with a midpoint of 1.1, applies to activated sludge when the residues created by preliminary physical treatment are included.

TABLE XVIII-4
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC MISCELLANEOUS

Item and Pollutant	Process or Activity	Treatment Process	% Reuse	Ref. No.	Description/Disposal of Residue
Beverages	SS, BOD_5	Sedimentation & biological stabilization	0	21	Organic sludge
Misc. food products	Particulates	Cyclone	0	11	Organic particles
	SS, BOD_5	Sedimentation & biological stabilization	0	340,348	Sludge of limestone, soil, organic
Textile mill prod.	Particulates	Lint filter	0	91	Lint
	SS, BOD_5	Sedimentation &/or coagulation plus activated sludge &/or trickling filter	0	349	Sludge of organic dyes, alum. or ferric salts, organics
Paving & roofing materials	Particulates	Cyclones	100	3,89,121, 169	Dust, asphalt particles
		Cyclones plus venturi scrubbers	96	89,121 169	Dust, asphalt particles
		Cylones plus fabric filters	100	89	Dust, asphalt particles
Rubber & misc. plastic products	Particulates	Baghouse precipitation	n.d.	254	Pigments, fillers, carbon black

TABLE XVII-4 (Cont.)
REUSE POTENTIALS FOR SOLID WASTE RESIDUES PRODUCED BY POLLUTION TREATMENT PROCESSES
SIC MISCELLANEOUS

Item and Pollutant	Process or Activity	Treatment Process	% Reuse		Description/Disposal of Residue
Leather and leather products	SS, BOD_5	Clarification, activated sludge, & filtration	0	63	Sludge of lime, limestone, sulfates, sulfides, chromium, organics
Concrete, gypsum & plaster products	Particulates	Baghouse	100	11	Input materials
Nonferrous rolling & drawing	SS, BOD_5	n.d.			
Nonferrous foundries	Particulates	Baghouse	80	11	Metals, metal oxides
Transportation equip.	SS, BOD_5	n.d.			
All transportation	Particulates	None	0	89	
Solid waste disposal	Particulates	Scrubbers	0	169	Ash particulates
		Elec. precip.	0	169	Ash particulates

TABLE XVIII-5
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANT								
Particulates:								
Misc. food prod.		Cyclones	100	1	70	1	100	1
Textile mill prod.		Lint filters	100	100	99	100	100	100
Paving & roofing mtls.		Cyclones	100	4,400	95	4,180	0	0
Rubber & misc. plastic prod.		Baghouse	100	5	n.d.	-	-	-
Concrete, gypsum & plaster prod.		Baghouse	100	3,580	99.5	3,560	0	0
Nonferrous foundries		Baghouse	100	30	96	30	20	6
Refuse systems	Incineration	Electrostatic precipitators	75	210	95	200	100	200
		Scrubbers	25	70[a]	95	70	100	70
	Open burning							
Total Residue from Air Pollution Control:				8,400	97	8,140	5	370

TABLE XVIII-5 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1971: SIC MISCELLANEOUS

				Weight in Kg x 10^6				
Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANT								
SS, BOD_5:								
Beverages		Sediment. & bio. stabilization	100	10	100	10	100	10
Misc. food prod.		Sediment. & bio. stabilization	100	40	100	40	100	40
Textile mill prod.		Sediment. &/or coag.;activ. sludge and/or trickling filter	100	260	80	210	100	210
Leather & leather products		Sedimentation	100	110	80	90	100	90
Nonferrous rolling & drawing		n.d.	n.d.					
Transportation equip.		n.d.	n.d.					
Total Residues from Water Pollution Control:				420	83	350	100	350
Total Residues from Air and Water Pollution Control:				8,820	96	8,490	8	720

TABLE XVIII-5 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1971: SIC MISCELLANEOUS

[a] Residues created during scrubbing are transferred to water as suspended solids, where they are further treated. Numbers in parentheses include these residues from scrubbing. The impact of scrubber residues on solid wastes explains the water pollutant estimates, since no solid wastes are created until treatment occurs following intermedial transfer.

TABLE XVIII-6
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1975: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANT								
Particulates:								
Misc. food prod.		Cyclones	100	1	70	1	100	1
Textile mill prod.		Lint filters	100	110	99	110	100	110
Paving & roofing mtls.		Cyclones	100	6,070	95	5,770	0	0
Rubber & misc. plastic prod.		Baghouses	n.d.	n.d.	n.d.		-	-
Concrete, gypsum & plaster prod.		Baghouses	100	4,300	99.5	4,280	0	0
Nonferrous foundries		Baghouses	100	40	96	40	20	7
Refuse system	Incineration	Electrostatic precipitators	75	250	95	240	100	240
		Scrubbers	25	80[a]	95	80	100	80
	Open burning							
Total Residues from Air Pollution Control:				10,850	97	10,520	4	440

TABLE XVIII-6 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1975: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Weight in Kg x 10^6 Net Solid Residues	% Not Reused	Weight in Kg x 10^6 Solid Waste Residues
WATER POLLUTANT								
SS, BOD_5:								
Beverages		Sediment. & bio. stabilization	100	15	100	15	100	15
Misc. food prod.		Sediment. & bio. stabilization	100	35	100	35	100	35
Textile mill prod.		Sedimen. &/or coag.; activ. sludge &/or trickling filter	100	320	80	250	100	250
Leather & leather products		Sedimentation	100	75	80	60	100	60
Nonferrous rolling & drawing			n.d.	n.d.	-	-	-	-
Transporation equip.			n.d.	n.d.	-	-	-	-
Total Residues from Water Pollution Control:				440	8	360	100	360
Total Residues from Air and Water Pollution Control:				11,290	96	10,880	7	800

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[a] See footnote (a), Table XVIII-5.

TABLE XVIII-7
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
1980: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANT								
Particulates:								
Misc. food prod.		Cyclones	100	1	70	1	100	1
Textile mill prod.		Lint filters	100	130	99	130	100	130
Paving & roofing mtls.		Cyclones & misc.	100	8,490	95	8,070	3	240
Rubber & misc. plastic prod.		Baghouses	n.d.	n.d.	n.d.			
Concrete, gypsum & plaster prod.		Baghouses	100	4,960	99.5	4,940	0	0
Nonferrous foundries		Baghouses	100	50	96	50	20	10
Refuse systems	Incineration	Electrostatic precipitators	80	990	95	940	100	940
		Scrubbers	20	250[a]	95	240	100	240
	Open burning							
Total Residues from Air Pollution Control:				14,870	97	14,370	11	1,560

TABLE XVIII-7 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1980: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANT								
SS, BOD_5:								
Beverages		Sediment. & bio. stabilization	100	20	100	20	100	20
Misc. food prod.		Sediment. & bio. stabilization	100	40	100	40	100	40
Textile mill prod.		Sediment. &/or coag.; activ. sludge &/or trickling filter	100	370	80	300	100	300
Leather & leather prod.		Sedimentation	100	100	80	80	100	80
Nonferrous rolling & drawing								
Transporation equip.								
Total Residues from Water Pollution Control:				530		490	100	440
Total Residues from Air and Water Pollution Control:				15,400	96	14,810	14	2,000

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[a] See footnote (a), Table XVIII-5.

TABLE XVIII-8

TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
AIR POLLUTANT								
Particulates:								
Misc. food prod.		Cyclones	100	1	70	1	100	1
Textile mill prod.		Lint filters	100	150	99	150	100	150
Paving & roofing mtls.		Cyclones & misc.	100	10,960	95	10,410	3	310
Rubber & misc. plastic prod.		Baghouses	n.d.	n.d.	n.d.			
Concrete, gypsum & plaster prod.		Baghouses	100	5,700	99.5	5,670	0	0
Nonferrous foundries		Baghouses	100	60	96	60	20	10
Refuse systems	Incineration	Electrostatic precipitators	80	1,140	95	1,080	100	1,080
	Open burning	Scrubbers	20	290^a	95	270	100	270
Total Residues from Air Pollution Control:				18,300	96	17,640	10	1,820

TABLE XVIII-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES

1985: SIC MISCELLANEOUS

Pollutant: Item	Process or Activity	Treatment Process	% Treated by Process	Weight in Kg × 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
WATER POLLUTANT								
SS, BOD_5:								
Beverages		Sediment & bio. stabilization	100	20	100	20	100	20
Misc. food prod.		Sediment. & bio. stabilization	100	50	100	50	100	50
Textile mill prod.		Sediment. &/ or coag.;activ. sludge &/or trickling filter	100	430	80	340	100	340
Leather & leather prod.		Sedimentation	100	90	80	70	100	70
Nonferrous rolling & drawing		n.d.	n.d.					
Transportation equip.		n.d.	n.d.					
Total Residues from Water Pollution Control:				590		480	100	480
Total Residues from Air and Water Pollution Control:				18,890	96	18,120	13	2,300

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[a] See footnote (a), Table XVIII-5.

from beverage wastewater treatments are sludges of basically organic nature, essentially cellular mases grown to lower BOD_5, with or without additional coagulant aids ($CaCO_3$, polyelectrolites, Fe^{+3}, Al^{+3}). The residues from miscellaneous food products wastewater treatment are a combination of inert solids (soil particles from beet washing and flumming) and cellular masses as above described. The sludges from textile mill products wastewater treatment may contain, apart from cellular masses grown for BOD_5 control, partially decomposed textile fibers, fats, starch, malt, tin, chromium, iron salts, phenols, and dye pigments.[430] If about 100,000 kkg of wool, grease and suint can be removed annually (assuming favorable prices),[121] then approximately one-half of the solid waste is grease and suint.

The sludges from leather and leather products wastewater treatment are composed mostly of lime, limestone, and calcium sulfate.[63,349] About 20 percent of the SS weight is grease, as calculated from data in the effluent guidelines report on wastewater from tanneries,[63] weighted by the production in each tannery category; cellular masses grown for BOD_5 reduction and partially decomposed organic matter constitute the rest of the sludge. The ratio of chromium to SS is 0.024, calculated as for grease above; the approximate chromium content of the sludge should therefore be about 2 percent.

Factors Affecting the Quality of the Data.

These sectors were studied in less detail than the previously discussed sectors. Here the National estimated discharges from previously published sources were taken as correct with the increases assumed to be proportional to industrial output through 1985. No breakdown of alternative manufacturing processes was made. These overall averages indicate a confidence level of 2 for the entire Section, indicating a possible 50 percent variation in the data.

Summary.

Untreated Discharges. This Section evaluated impacts on solid waste of pollution control activities in important miscellaneous industrial sectors not discussed in previous Sections. Untreated discharges of air and water pollutants potentially impacting on solid waste management are mainly particulates (largely from paving and roofing materials, concrete, plaster, and gypsum production). Sulfur oxides (largely from automobile transportation)will have minimal impact on solid waste management. Particulate emissions from all sectors evaluated are forecast to increase from 8.4 billion to 18.3 billion kg between 1971 and 1985; sulfur oxides emissions from these sectors were forecast to increase from 2.9 billion to 4.7 billion kg during the same period. Water pollutant discharges from the sectors evaluated are mainly BOD_5 and suspended solids. Textile mills account for a large portion of both these water pollutants, and the beverage industry also discharges significant amounts of BOD_5. Total BOD_5 discharges were forecast to increase from 0.9 to 1.5 billion kg between 1971 to 1985; total suspended solids discharges were forecast to increase from 448 to 659 million kg during this period.

Treatment Methods and Reuse. Particulate emissions from these assorted industries will be controlled by cyclones, filtration, baghouses, and electrostatic precipitation; which specific treatments are used varies among the individual industries. Paving and roofing material production emissions will be controlled by cyclones alone, cyclones and scrubbers, or cyclones and fabric filters. Particulate emissions from concrete, plaster, and gypsum production will be controlled by baghouses. Discharges to water by the beverage industry (BOD_5) will be controlled by sedimentation and biological stabilization. Discharges to water from textile mills (BOD_5 and SS) will be controlled by sedimentation, coagulation plus activated sludge, and trickling filters. Particulates trapped by pollution controls for most industries evaluated in this Section are capable of extensive reuse; reuse of residues derived from water pollution control, on the other hand, is minimal.

Residues Generated from Pollution Control: Types and Amounts. Total residues from pollution control for the sectors evaluated in this Section were forecast to increase from 720×10^6 kg in 1971 to $2,300 \times 10^6$ kg in 1985. Textile mills, paving and roofing materials production and incineration of municipal refuse are important contributors to these solid residues derived from pollution control.

SECTION XIX

HAZARDOUS SOLID WASTE RESIDUES

Introduction.

Hazardous wastes are evaluated in this Section in three steps. First, hazardous wastes are defined using a decision algorithm to guide evaluations. Second, hazardous waste streams, either resulting from air and water pollution controls or producing hazardous residues as a result of current or future pollution controls, are listed. Third, the probable pollution controls and solid residues resulting from these controls are evaluated with respect to the degree of hazard associated with each residue.

The Definition of Hazardous Wastes.

A recent report[237] delineated two approaches to defining hazardous wastes. The first, the pure-compound approach, is simple in concept and rapid in evaluation in that most chemistry handbooks list the hazards of pure compounds. The second, the waste-stream approach, more realistically measures the hazards of wastes in the environment, requiring laboratory tests beyond the scope of the pure-compound approach for constituent compounds; standard tests and scales designed by national safety groups are employed in this second method.

Each waste may be evaluated in terms of seven defined hazards: flammability, reactivity, toxicity, irritativity, radioactivity, bioconcentration, and genetic activity.[237] The pure-compound approach analyzes each compound present in a waste stream for individual hazard levels after identification (in the laboratory, if necessary) of pure compounds. The waste stream approach, extending the pure-compound analysis, involves performing standard tests of hazard level for the actual waste stream, thus testing all interactions and then byproducts. Chemical interactions in the waste stream can create hazardous conditions undetected by pure-compound analysis, including production of hazardous byproducts like HCl, Cl_2, and explosives; catalysis of exothermic reactions; and increased toxicity of poisons in the presence of solvents, permitting their absorption into the skin.[237]

Figure XIX-1 presents the algorithm developed by Battelle Memorial Institute[237] for standard laboratory tests on waste stream samples. Various National groups such as the National Fire Protection Agency (NFPA), EPA, and FDA, have defined these tests and hazard scales.

Industry Descriptions.

Most industries produce some hazardous solid waste residues, with some notable exceptions such as the food processing industry. Certain industries may be considered major sources of hazardous wastes: metal mining and smelting, pesticide manufacturing, nuclear power generation, paint and dye manufacturing, pharmaceutical manufacturing, and munition processing. These major and other lesser services of hazardous residues have been described in their respective industry sections.

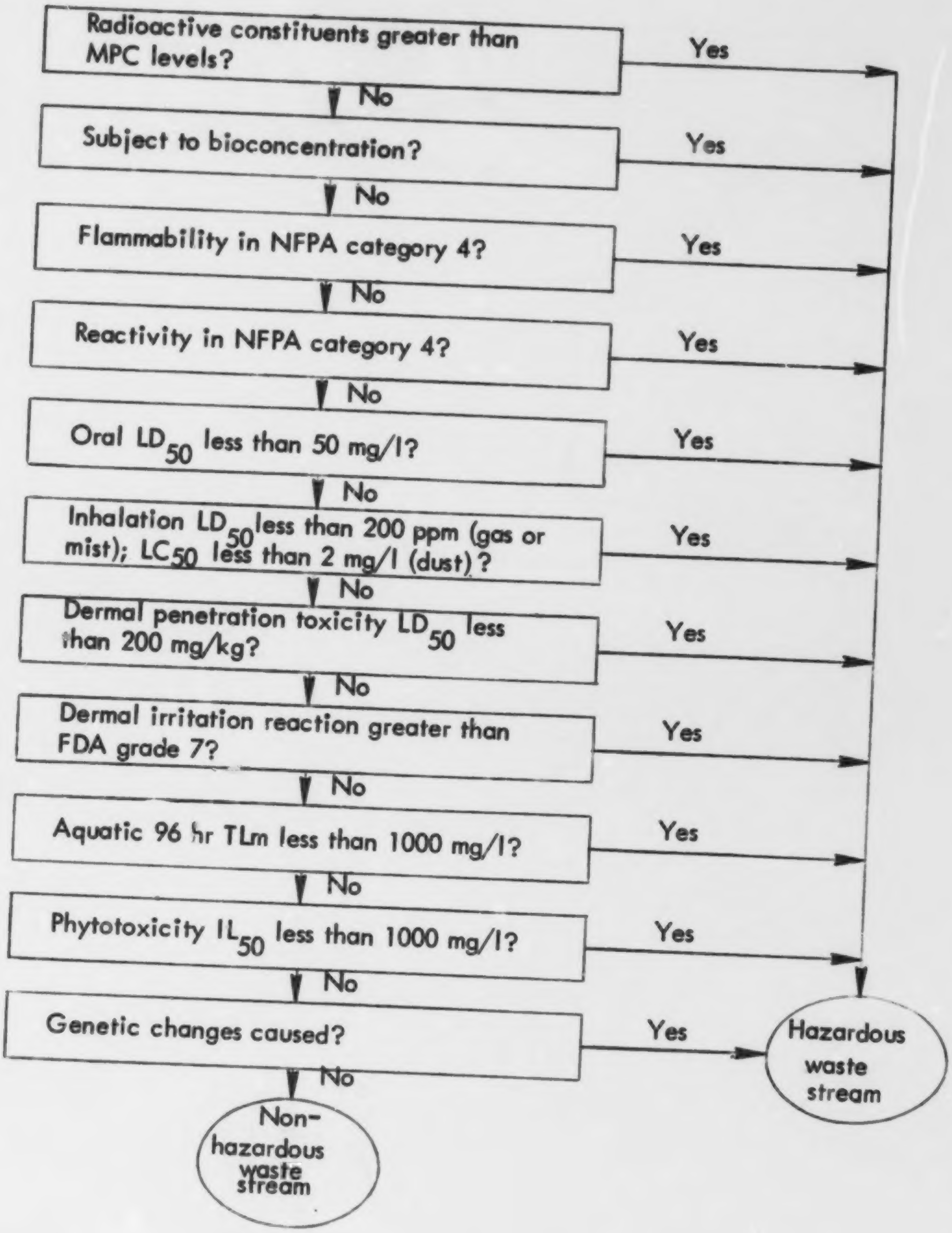
Radioactive constituents greater than MPC levels?
Subject to bioconcentration?
Flammability in NFPA category 4?
Reactivity in NFPA category 4?
Oral LD_{50} less than 50 mg/l?
Inhalation LD_{50} less than 200 ppm (gas or mist); LC_{50} less than 2 mg/l (dust)?
Dermal penetration toxicity LD_{50} less than 200 mg/kg?
Dermal irritation reaction greater than FDA grade 7?
Aquatic 96 hr TLm less than 1000 mg/l?
Phytotoxicity IL_{50} less than 1000 mg/l?
Genetic changes caused?
Yes
No
Hazardous waste stream
Non-hazardous waste stream

FIGURE XIX-1
DECISION ALGORITHM FOR
DETERMINING WASTE STREAM
HAZARDOUSNESS

Legend:

Term	Equivalent
MPC	AEC's maximum permissible level.
NFPA	National Fire Protection Agency.
LD_{50}	Lethal dosage (mg/l) for 50% of large test animal population.
TLm	Lethal threshold for 50% of fish and other aquatic organisms for constant 96 hour exposure.
IL_{50}	Inhibiting limit reducing test culture to 50 percent control in biomass, cell count, or photosynthesis after 14 days.

FIGURE XIX-1 (Cont.)
DECISION ALGORITHM FOR
DETERMINING WASTE STREAM
HAZARDOUSNESS

Economic Forecasts.

Table XIX-1 lists production levels of key hazardous waste producing industries by SIC category for the years 1971, 1975, 1980 and 1985. The economic data, taken largely from Predicasts[68] predictions, may be given a confidence level of 4, indicating a ± 10 percent possible variation in the data. Table XIX-2 converts the economic forecasts to growth in production using 1971 as the base year.

As may be seen from these predictions, the largest growth in production by 1985 (more than double) is expected from inorganic chemicals, synthetics, drugs, organic chemicals, industrial machinery, electrical machinery, aircraft, and power utilities.

Discharge Inventory for Pollutants Capable of Producing Hazardous Solid Waste Residues.

Table XIX-3 lists hazardous waste streams known to be significant air and water pollutants. The most complete hazardous waste report to date (1973) has delineated four major groups of hazardous waste streams:[237] numerous aqueous inorganic waste streams requiring water treatment; numerous aqeous organic waste streams requiring water treatment; a number of sludges from wet scrubbers and water treatment; and radioactive wastes from the power cycle, various industries, and the Federal Government. Many industrial hazardous waste contributions are not quantified in Table XIX-3. Missing are hazardous mine waters, hazardous dusts and evaporated chemicals, hazardous chemicals washed from equipment and plants, and hazardous wastes from many small industries. However, even lacking a complete list, a rough estimate of both quantity and composition of hazardous residues is still possible. A low confidence level of 1, or greater than 100 percent variation, is probable in the estimated values.

For hazardous aqueous inorganic solution waste streams, the largest contribution for which data are available is cold finishing wastes from SIC 331 ($2,000 \times 10^6$ kg for 1971). Other important contributions to aqueous inorganic solutions are cadmium ore wastes (SIC 1099), chlorine production brine (SIC 2812), cellulose ester production waste (SIC 2821), petroleum wastes (SIC 291), metal finishing chromic acid (SIC 34), and aircraft plating waste (SIC 372). The largest contributions to hazardous organic solution waste streams are nitribenzene from waste rubber from SIC 2822 and drug manufacture wastes from SIC 283 (both $2,000\ 410^6$ kg in 1971); however, both these inorganic solutions are very dilute, and the amount of dry solid hazardous wastes is not as large as suggested by this solution weight figure. Other important contributions to organic solution waste streams are acetaldehyde (SIC 281) and pesticide and herbicide manufacture wastes (SIC 2879). Hazardous waste streams in sludge form are produced in significant quantities from copper refining flues (SIC 1021), paint production (SIC 285), smelting (SIC 33), and battery manufacture (SIC 3691). The main contributor to radioactive wastes is the steam electric power industry's (SIC 491)use of nuclear power plants. The concentrations of hazardous material and overall suspended solids is a factor of process, plant, and individual runs.[237] Thus,many fundamental chemical characteristics may vary within a single identified waste stream. A complete analysis would require study of small segments of industry at the level of seven-digit SIC categories.

TABLE XIX-1
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Metal mining	10	Index[a]								
Textile mill products	22				121.4	154	178	202	68	1973
Wood pulp	2611				108.6	132	154	177		
Industrial inorganic	281				119.3	140	167	195		
chemical production					107.0	132	171	215		
Synthetic materials	282									
Drugs	283				156.6	232	334	462		
Paints	285				157.8	230	322	440		
Industrial organic	286				114.1	135	151	169		
chemicals					119.0	170	217	272		
Agricultural chemicals	287									
Petroleum refining	291				99.3	123	145	168		
Leather and leather	31				115.7	135	159	184		
products					87.4	97	101	105		
Glass products										
Primary metals	33				116.8	154	187	223		
Steel works	331				100.9	131	153	176		
Refining non-ferrous	333				97.0	126	143	160		
metals					121.1	159	190	225		
Fabricated metal products	34				107.5	133	157	179		
Special and general industrial machinery	3555,6				89.7	124	154	187		
Electrical machinery	36				98.3	144	186	233		
Aircraft production	372				62.3	88	112	137		

TABLE XIX-1 (Cont.)
SUMMARY OF AVAILABLE INDUSTRIAL GROWTH FORECASTS FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Physical Unit (Metric)	Other Years		Forecast Quantity				Ref.	
			Year	Quantity	1971	1975	1980	1985	No.	Year Made
Overall manufacturing, mining, and utilities	41	Index			106.8	137	167	201	68	1973
Power utilities	491,2				133.9	177	236	314		

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[a] Index uses 1967 level as 100

TABLE XIX-2
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Metal mining	10	Ratio to 1971	1	68	1.27	68	1.47	68	1.66	68
Textile mill pond	22		1		1.22		1.42		1.63	
Wood pulp	2611		1		1.17		1.40		1.63	
Industrial inorganic chemicals	281		1		1.23		1.60		2.01	
Synthetic materials	282		1		1.48		2.13		2.95	
Drugs	283		1		1.46		2.04		2.79	
Paints	285		1		1.18		1.32		1.48	
Industrial organic chemicals	286		1		1.43		1.82		2.29	
Agricultural chemicals	287		1		1.24		1.46		1.69	
Petroleum refining	291		1		1.17		1.37		1.59	
Leather and leather products	31		1		1.11		1.16		1.20	
Glass products	32		1		1.32		1.60		1.91	
Primary metals	33		1		1.30		1.52		1.74	
Steel works	331		1		1.30		1.47		1.65	
Refining non-ferrous metals	333		1		1.31		1.57		1.86	
Fabricated metal-products	34		1		1.24		1.46		1.67	
Special and general industrial machinery	3555,6		1		1.38		1.72		2.08	
Electrical machinery	36		1		1.46		1.89		2.37	

TABLE XIX-2(Cont.)
COMPREHENSIVE FORECAST OF INDUSTRIAL GROWTH
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Physical Units (Metric)	1971		1975		1980		1985	
			Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.	Quantity	Ref. No.
Aircraft production	372	Ratio to 1971	1	68	1.41	68	1.80	68	2.20	68
Power utilities	491,2		1		1.32		1.76		2.35	
Overall manufacturing, mining, and utilities			1		1.28		1.56		1.88	

TABLE XIX-3
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Pollutant	SIC	10^6 Kg Pollutant Discharged[a]			
		1971	1975	1980	1985
Aqueous Inorganic solutions:					
Zinc ore acid wash	1031	n.d.			
Mercury ore extraction waste	1092	n.d.			
Cadmium ore waste	1099	90	110	130	150
Chromate wastes from textile dying	22	9	11	13	15
Chlorine production brine	2812	50	60	80	100
Arsine production waste	2813	0.005	0.006	0.008	0.01
Pigment wastes	2816	n.d.			
Potassium chromate waste prod.	2819	0.5	0.6	0.8	1.0
Cyanide prod. waste	2819	n.d.			
Cellulose ester prod. waste	2821	20	30	40	60
Urethane prod. waste	2821	n.d.			
Polycarbonate polymer prod. waste	2821	n.d.			
Wood preservative waste	2865	n.d.			
Hydrazine prod. waste	2869	n.d.			
Agriculture chemical prod. wastes	287	n.d.			
Agriculture intermediate wastes	287	0.09	0.11	0.13	0.15
Ammonia sulfate prod. wastes	2873	0.0005	0.0006	0.0007	0.0008

TABLE XIX-3 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Pollutant	SIC	10^6 Kg Pollutant Discharged[a]			
		1971	1975	1980	1985
Agriculture pesticide prod. arsenic wastes	2879	n.d.			
Mercury fungicide prod. wastes	2879	n.d.			
Pesticide arsenate wastes	2879	n.d.			
Pesticide arsenic wastes	2879	n.d.			
Petroleum wastes	291	40	50	50	60
Chrome tanning liquor	31	9	10	10	11
Mirror prod. waste	3231	4	5	6	8
Cold finishing wastes	331	2000	3000	3000	3000
Consolidated steel waste	331	200	300	300	300
Stainless pickling wastes	3312	20	30	30	30
Brass mill wastes	333	20	20	30	30
Total metal finishing wastes	33	20	30	30	30
Aluminum anodizing bath	33	4	5	6	7
Brass plating wastes	33	n.d.			
Cadmium plating wastes	33	0.5	0.7	0.8	0.9
Chrome plating wastes	33	n.d.			
Cyanide copper plating wastes	33	0.9	1.2	1.4	1.6
Finishing effluents	33	n.d.			
Metal draining wastes	33	n.d.			
Plating preparation wastes	33	n.d.			
Silver plating wastes	33	n.d.			

TABLE XIX-3 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Pollutant	SIC	10^6 Kg Pollutant Discharged[a]			
		1971	1975	1980	1985
Zinc plating wastes	33	n.d.			
Metal finishing chromic acid	34	20	20	30	30
Photography wastes	3555	0.002	0.003	0.003	0.004
Circuitry manufacturing wastes	36	0.2	0.3	0.4	0.5
Battery manufacturing wastes	36	n.d.			
Aircraft plating wastes	372	20	30	40	40
Military plating wastes	9711	n.d.			
Military sodium chromate	9711	n.d.			
All cooling tower wastes		9	12	14	17
Aqueous organic solutions:					
Dimethyl sulfate prod. wastes	2611	0.09	0.11	0.13	0.15
Acetaldehyde via ethylius oxidation	281	40	50	60	80
Residue of ethylene dichloride & vinyl chloride	2821	9	13	19	27
Nitrobenzene from rubber[b] wastes	2822	2000	3000	4000	6000
Synthetic fiber prod. wastes	2824	n.d.			
Drug manufacture wastes[b]	283	2000	3000	4000	6000
Dye manufacturing wastes	2865	n.d.			
Chlorinated hydrocarbon pesticide prod. waste	2879	90	110	130	150

TABLE XIX-3 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Pollutant	SIC	10^6 Kg Pollutant Discharged[a]			
		1971	1975	1980	1985
Organic herbicide prod. wastes	2879	200	200	300	300
Organic-phosphate pesticide prod. wastes	2879	30	40	40	50
Organic pesticide prod. wastes	2879	100	120	150	170
Phenoxy herbicide prod. wastes	2879	20	20	30	30
Nitrite pesticide wastes	2879	n.d.			
Organic arsenicals from cacolylate prod. wastes	2879	n.d.			
Total pesticide/herbicide prod. wastes		450	500	670	720
Utilities and electric station wastes	49	10	10	20	20
Sludges:					
Arsenic wastes from Cu refining flues	1021	40	50	60	70
Solvent-based paint sludge	285	40	50	50	60
Water-based paint sludge	285	30	40	40	40
Petroleum waste brine sludge	2911	4	5	5	6
Iron product waste sludge	331	6	8	9	10
Arsenic trioxide from smelting	333	20	30	30	40

TABLE XIX-3 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Pollutant	SIC	10^6 Kg Pollutant Discharged [a]			
		1971	1975	1980	1985
Battery manufact. waste sludge	3691	50	70	90	120
Arsenic trichloride recovered from coal	49	6	8	11	14
Military paris green	9711	0.03	0.03	0.04	0.04
Radioactive wastes:					
Mill tailings	49	1,100 (.21x10^4)[d]	6,600(1.2x10^4)[d]	18,000(3.4x10^4)[d]	33,000(6.3x10^4)[d]
Conversion solids	49	270 (3.2x10^4)	1,600(9 x 10^4)	4,500(53 x 10^4)	8,500(98 x 10^4)
Gases from enrichment	49	0.00004(0.19)	0.0003(0.19)	0.0006(0.53)	0.0013(0.98)
Liquids from enrichment	49	0.0003(.25)	0.002(1.5)	0.005(4.1)	0.010(7.5)
Gases from fuel fabrication	49	0.00003(0.5)	0.0002(0.31)	0.0004(0.85)	0.0009(1.6)
Liquids from fuel fabrication	49	10(1.2)	60(7)	160(20)	300(37)

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[a] 10^6 kg weights, except where noted, are wet weights (pollutants plus aqueous medium).

[b] Extremely dilute; less hazardous than weight figures would suggest.

[c] These weights for radioactive compounds only.

[d] Figures in prentheses indicate total annual curies.

An important assumption in projecting hazardous waste streams is that by 1985 industrial methodologies will not change sufficiently to affect the composition of hazardous wastes. However, it is possible that some waste streams may dry up while others may begin to flow. For example, improved plating equipment may reduce heavy metal concentration in plating wastewater. If these changes in fact occur, projected waste streams composition will vary in the particular sectors involved.

Little information is available concerning hazardous residues discharged to the air. Based on industrial experience, these residues are similar in concentration but much smaller in quantity than residues from water treatments. The weight of filter elements will contribute to the amount of these solid residues. Since almost all hazardous wastes listed in Table XIX-3 are in solution, evaporation will be the major mechanism producing air pollution. In chemical plants, powdered chemicals will produce dust pollution, but these residues may be partially reclaimed.

In order to estimate the quantities of dry hazardous solids listed in Table XIX-3, assumptions concerning waste concentrations in the total waste stream were necessary due to the dearth of available information concerning National industrial hazardous waste stream solids concentrations. The following concentration levels were assumed: inorganic aqueous solutions: high of 1.0, intermediate of 0.5, and low of 0.1 percent; organic aqueous solutions, 1 percent; and sludges, 5 percent. It should be realized that:1) these concentrations represent all solids in the waste stream, not just purely hazardous wastes; and 2) these concentrations are estimates based largely, due to the lack of more specific data, on a general knowledge of current industrial sludge practices and estimates of the solubility of various solids. With regard to current industrial practice, it was assumed that those hazardous organic and inorganic wastes which are considered hazardous in relatively large concentrations are relatively easily removed from the waste stream,and that certain metallic ions are recovered due to their resale value.

Radioactive residues are considered separately from non-radioactive residues in this Section. The radioactive wastes from nuclear power plants and fuel reprocessing plants have been discussed in Section XVI, Steam Electric Power Plants. Low-level wastes compose the major quantity of radioactive wastes. The majority of the wastes treated in this Section are from the milling of uranium ore and the resultant use of tailing ponds. These wastes are of low level radioactivity but contain many long-lived isotopes. Increasingly stringent pollution laws will not significantly increase solid residues derived from controls since current practices capture these radioactive solids. Increased use of nuclear power will, however, greatly increase the wastes stored at AEC-controlled sites.

Likely Pollution Treatment Processes.

Non-radioactive and radioactive wastes are treated by different processes. Non-radioactive hazardous wastes are from many distributed streams, subject to few controls at present, and will be subject to many changes by 1985. The radioactive waste stream, on the other hand, is simpler, subject to more advanced technology, and consequently subject to fewer changes between 1971 and 1985. Discussion here will focus on water pollution controls, as hazardous wastes subject to air pollution control constitute a very small proportion of total hazardous wastes subject to treatment. For non-radioactive pollutants, types of air controls will remain relatively constant with increased control levels between 1971 and 1985. Types of water treatment, however, will change dramatically, from mere evaporation ponds at present to complete advanced water treatment by 1985. Air pollution controls will use filter media and electrostatic precipitators to capture evaporated and particulate hazardous pollutants, followed by secure land disposal (or reuse in a few cases). Waste treatment will become a complex and expensive operation, with many smaller plants using tank trucks to transport hazardous liquid wastes to treatment facilities.

Advanced water treatment will be necessary as the evaporation ponds presently in wide use are prohibited by law. Today industry often uses very shallow ponds to hold liquid hazardous wastes and residues, allowing evaporation. This permits the hazardous waste to blow and leach into the environment; leaching into water supply sources has resulted in reported deaths of animals and poses special dangers to man as well. Current alternatives for wastes too dangerous for evaporation are deep-well injection and far ocean disposal. Most ocean disposals are now banned, but some deep well disposal currently occurs. In a few cases, liquids are now stored indefinitely until a solution to the disposal problem develops. Table XIX-4 lists tonnages and costs of the major ocean disposals in 1968. Most of these have since been discontinued, except municipal sludge disposal.

Table XIX-5 lists the possible hazardous waste stream treatments and disposal alternatives, and indicates those selected in a recent report as constituting a model treatment disposal system. The latter model treatment disposal system (indicated by asterisks in Table XIX-5) is the basis for the following predictions of treatments because these methods will be used in the near future, while others listed are still in the experimental stage.

Figure XIX-2 schematizes a basic treatment system for non-radioactive hazardous wastes based on the present state-of-the-art. This system is most amenable to the larger hazardous waste processing facilities located in heavily industrialized areas. Neutralization, precipitation, oxidation, and reduction will occur in large, mixing tanks, identified in Figure XIX-2 as chemical treatments. Neutralization and chemical precipitation will drop heavy metals from solution, while oxidation of cyanide (CN^-) and reduction of chromium (CrO_3) will drop them from solution. Other non-hazardous chemicals will also drop out. Liquids-solids separation will occur in sedimentation/floculation tanks, with sludge moving to an evaporator and wastewater moving to carbon filters. Carbon absorption will remove hazardous organics from the water, or chlorine, ozone, potassium permanganate, or peroxide will oxidize these organics, depending on the least expensive procedure. Biological digestion is an alternative to carbon filtration but a high salt content and variations in waste quantities will endanger any cultures. After carbon filtration, the water will be released while the carbon will be regenerated by thermal or steam treatments.

TABLE XIX-4

OCEAN DISPOSALS IN PACIFIC, ATLANTIC, AND GULF COAST WATERS FOR THE YEAR 1968[279]

Waste Type	Pacific Coast Annual Weight in kkg (s tons)	Atlantic Coast Annual Weight in kkg (s tons)	Gulf Coast Annual Weight in kkg (s tons)	Total Annual Weight in kkg (s tons)	Percent of Total
Dredging spoils	7,550,000 (8,320,000)	28,014,000 (30,880,000)[a]	12,000,000 (13,000,000)	47,400,000 (52,200,000)	84
Industrial wastes bulk	890,000 (981,000)	2,732,000 (3,011,000)	630,000 (690,000)	4,248,000 (4,682,000)	8
containerized	270 (300)	2,000 (2,200)	5,400 (6,000)	7,700 (8,500)	1
Refuse, garbage[b]	24,000 (26,000)			24,000 (26,000)	1
Sewage sludge[c]		4,062,000 (4,477,000)		4,062,000 (4,477,000)	7
Miscellaneous	180 (200)			180 (200)	1
Construction and demolition debris		521,000 (574,000)		521,000 (574,000)	1
Explosives		13,800 (15,200)		13,800 (15,200)	1
Total, all wastes[d]	8,462,000 (9,327,500)	35,344,000 (38,959,400)	12,425,000 (13,696,000)	56,231,000 (61,982,900)	100

TABLE XIX-4 (Cont.)

OCEAN DISPOSALS IN PACIFIC, ATLANTIC, AND GULF COAST WATERS FOR THE YEAR 1968[279]

[a] Includes 180,000 kkg of fly ash.

[b] At San Diego 4,300 kkg vessel garbage disposal at $280,000 per year was discontinued in November 1968.

[c] Tonnage on wet basis. Assuming average 4.5 percent dry solids, this amounts to approximately 180,000 kkg dry solids per year being barged to sea.

[d] Radioactive wastes omitted. There were no dumps during 1968. Average annual disposal in 1969-1970 was 3.8 kkg.

[e] Estimated costs were increased proportionately for each area from the original tonnage/cost data.

TABLE XIX-5
ALTERNATIVE TREATMENT AND DISPOSAL METHODS FOR HAZARDOUS WASTE STREAMS[237,278]

Treatments	Disposal
Reverse osmosis	Land burial
Electrodialysis	Sanitary landfill*
Dialysis	Deep-well injection*
Ion exchange	Ocean dumping*
Trickling filter	
Activated sludge	
Aerated lagoon	
Anaerobic lagoon	
Spray irrigation	
Waste stabilization pond	
Combustion	
Pyrolysis	
Neutralization	
Precipitation	
Oxidation*	
Reduction*	
Flocculation*	
Sedimentation*	
Filtration*	
Ammonia stripping*	
Carbon adsorption*	
Incineration*	
Evaporation*	

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* Indicates alternatives selected for a model hazardous waste processing/disposal system by Batelle Memorial Institute.[237]

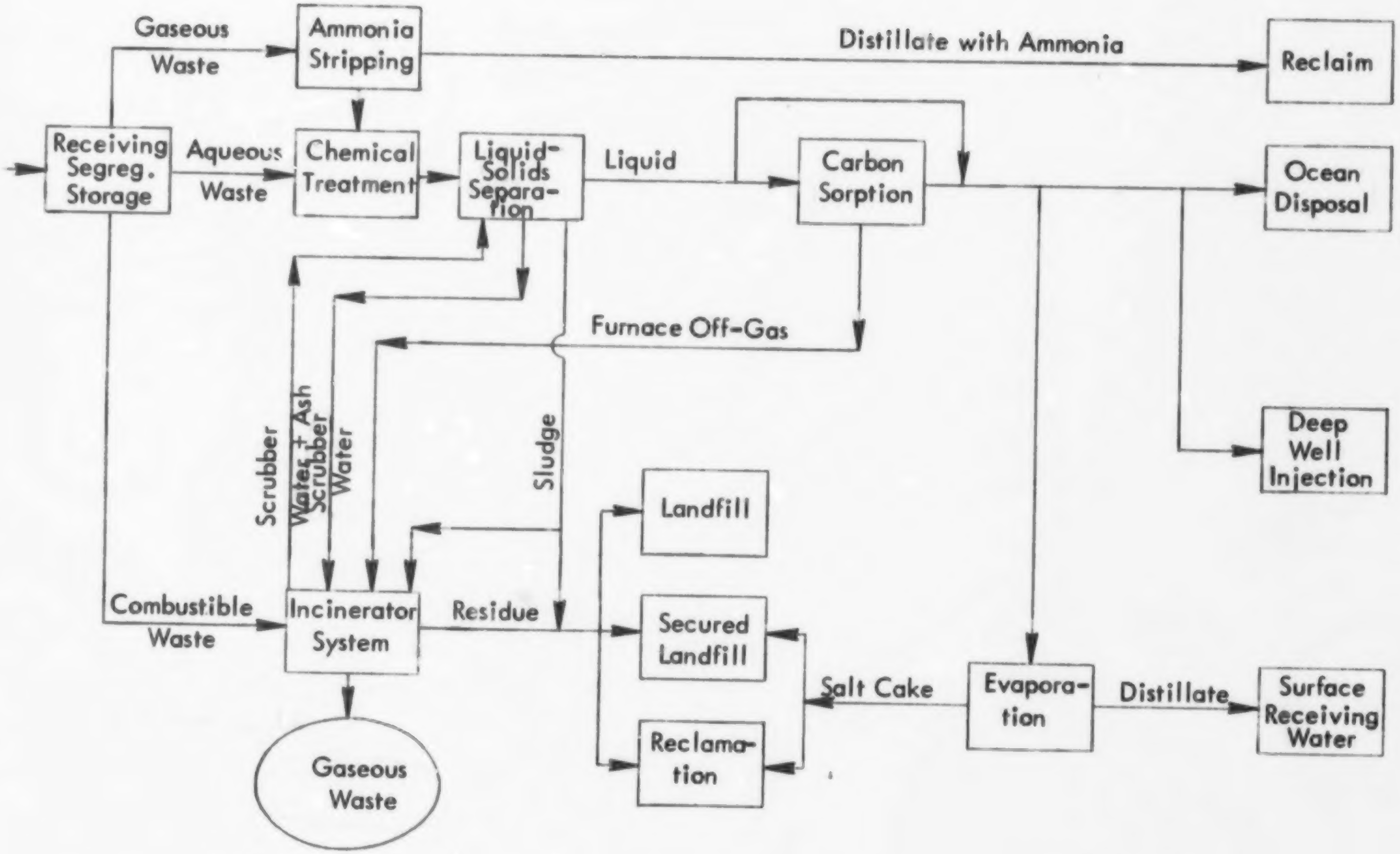
Gaseous Waste
Ammonia Stripping
Distillate with Ammonia
Reclaim
Receiving Segreg. Storage
Aqueous Waste
Chemical Treatment
Liquid-Solids Separation
Liquid
Carbon Sorption
Ocean Disposal
Furnace Off-Gas
Scrubber Water + Ash
Scrubber Water
Sludge
Deep Well Injection
Landfill
Combustible Waste
Incinerator System
Residue
Secured Landfill
Salt Cake
Evaporation
Distillate
Surface Receiving Water
Reclamation
Gaseous Waste

FIGURE XIX-2
TREATMENT PROCESS SCHEMATIC:
NON-RADIOACTIVE HAZARDOUS WASTES[237]

Special treatments such as ammonia stripping are required for some wastes, but these are of secondary interest. The methods of chemical treatment of hazardous wastes will center on neutralization by adding acids to bases and the use of lime. Oxidation of cyanide (CN^-) will use chlorine and sodium hydroxide, as in equation XIX-1.

$$\text{(XIX-1)}\quad 2NaCN + 5Cl_2 + 12\,NaOH \longrightarrow 10\,NaCl + 2\,Na_2CO_3 + N_2\,(g) + H_2O.$$

About four units of chloride and nine units of sodium hydroxide are consumed per one unit of cyanide, with heavy metal complexes of cyanide requiring long reaction times. Reduction of chromium will use sulfur dioxide, as in equation XIX-2.

$$\text{(XIX-2)}\quad 3\,SO_2 + 3H_2O + 2CrO_3 \longrightarrow Cr_2(SO_4)_3 + 3H_2O.$$

About one unit of SO_2 is consumed per unit of chromium. Liquids–solids separation will produce a sludge laced with heavy metals and salts. A large fraction of the solids content will be non-hazardous. The sludge may or may not be concentrated by evaporation before secure landfilling.

Incineration of combustible hazardous wastes (mainly organic pesticides and explosives) and spent carbon will eliminate organic hazardous wastes and reduce waste volume. Incineration is not safe when heavy metals like mercury and arsenic are present, so steam regeneration of carbon may be used. Incinerator residues are probably safe enough to dispose to sanitary landfills, so that incineration use will increase as technology advances to include safe incinerators; however, incineration and air pollution technological costs are high.

The alternatives in Figure XIX-2 cover most major methods of treating hazardous waste streams. In actual applications, only a subset of this system is usually applied, with the more sophisticated systems existing in highly industrialized areas using nearly the complete system.

Table XIX-6 summarizes categories of treatment processes applicable to hazardous wastes. These treatment categories group together treatments which are applicable to similar waste streams.

Table XIX-7 uses the categories established in Table XIX-6 to indicate the likely treatments to be applied to hazardous waste streams and to estimate the resultant solid waste residues. The ratios of residue per kilogram of hazardous waste removed are as presented in the discharge inventory discussion above.

TABLE XIX-6

LEGEND OF TREATMENT PROCESSES USED IN TABLES XIX-7 THROUGH XIX-11

Code	Treatment Processes	
I	Neutralization: of acids with bases. Precipitation: induced by small amounts of chemicals. Oxidation: by sodium hydroxides. Reduction: by sulfur dioxides. Sedimination/flocculation: in larger basins.	
II	Carbon Absorbtion: or Oxidation:[a] by chlorines, oxides, peroxides, or potassium permanganates.	Regeneration: by thermal or steam.
III	Evaporation: or Secure Landfilling: alone or Deep-Well Injection:	Secure Landfilling:

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[a] Estimated to be used on an insignificant fraction of total stream.

TABLE XIX-7

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Stream	Cost Range: $ per Physical Unit	Ref. No.
Inorganic aqueous solutions:							
Zinc ore acid wash	1031	Hg^{+2}	1[a]	90–99	0.01		See text
Mercury ore extraction waste	1092	Hg^{+2}			0.01		
Cadmium ore waste	1099	Cd^{+2}			0.01		
Chromate wastes from textile dying	22	CrO_3^{-2}			0.005		
Chlorine production brine	2812	Hg^{+2}, asbestos, Pb^{+2}, H_2SO_4			0.005		
Arsine production wastes	2813	$A_sO_4^{-3}$			0.005		
Pigment wastes	2816	CrO_3^{-2}			0.01		
Potassium chromate prod. wastes	2819	CrO_3^{-2}			0.001		
Cyanide production waste	2819	NaCN			0.001		
Cellulose ester prod.	2821	$HgCl_2$, H_2SO_4			0.005		
Arethane prod. waste	2821	Hg^{+2}			0.005		
Polycarbonate polymer prod.	2821	Phosgene			0.005		
Wood preservative wastes	2865	Pentachlorophenol			0.001		
Hydrazine prod. wastes	2869	NaOH			0.001		

TABLE XIX-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Stream	Cost Range: $ per Physical Unit	Ref. No.
Agriculture chem. prod. waste	287	NO_3^-	1[a]	90-99	0.01		See text
Agriculture interm. wastes	287	NO_3^-, Na_2CrO_4 $ZnCl_2$			0.01		
Ammonium sulfate prod. wastes	2873	Na_2CrO_4			0.001		
Agriculture pesticide prod. arsenic wastes	2879	AsO_3			0.005		
Mercury fungicide prod. wastes	2879	Hg^{+2}			0.005		
Pesticide arsonate waste	2879	AsO_4^{-2}			0.005		
Pesticide arsenic waste	2879	As_2O_3			0.005		
Petroleum wastes	291	Pb^{+2}, Cu^{+2}, CN, NO_3			0.005		
Chrome tanning liquor	31	Na_2CrO_4, Na_2SO_4			0.005		
Mirror prod. waste	3231	$Cr(SO_4)$, $Fe(SO_4)$			0.001		
Cold finishing wastes	331	NaCN, $FeSO_4$, Na_2CrO_4, $ZnCl_2$ solvents			0.001		

TABLE XIX-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Streams	Cost Range: $ per Physical Unit	Ref. No.
Consolidated steel waste	331	Phenyls, NaCN, NaF, $Cr(SO_4)$ HCl, $ZnCl_2$	I[a]	90–99	0.001		See text
Stainless steel pickling liquor	3312	HF, H_2SO_4, Fe^{+2} CrO_3^{-2}, Ni^+, NO_3^-			0.005		
Brass mill wastes	333	Cu^{+2}, Zn^{+2}, SO_4^{-2} $Na_2Cr_2O_2$ bright dip liquor			0.001		
Metal finishing wastes	33	Cu salts			0.001		
Aluminum anodizing bath	33	Cr, $AlSO_4$, H_2SO_4			0.001		
Brass plating wastes	33	$ZnCrO_3$, $Cu(CN)_2$, Zn(CN)2			0.001		
Cadmium plating wastes	33	Cd^{+2}, $Cd(CN)_2$, HCN			0.001		
Chrome plating wastes	33	CrO_3^{-2}, $Cr(SO_4)_2^{-2}$, Cu^{+2} Fe^{+2}			0.001		
Cyanide copper plating wastes	33	HCN, $Cu(CN)_2$			0.001		
Finishing effluents	33	Metals, CN^-, SO_4^{-2} Cr(OH), $Na_2Cr_2O_2$			0.001		
Metal cleaning wastes	33	Cu salts			0.001		

TABLE XIX-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Stream	Cost Range: $ per Physical Unit	Ref. No.
Plating preparation wastes	33	Cr^{+6}, Cu^{+}, Ni^{+2}, HF	1a	90-99	0.005		See text
Silver plating wastes	33	AgCN, HCN			0.005		
Zinc plating wastes	33	$Zn(CN)_2$, NaOH, HCN			0.001		
Metal finishing chromic acid	34	CrO_3^{-2}			0.001		
Photography wastes	3555	$Ag^{+}, (NH_4)_2 CrO_4$			0.001		
Circuitry manufact. wastes	36	CN^{-}, metals, HCl, H_2SO_4, CCl_4			0.001		
Battery manufact. wastes		Hg^{+2}, CdO, As^{+}, KOH			0.005		
Aircraft plating wastes	372	$Cd^{+2}, CN^{-}, Na^{+}, OH^{-}$			0.005		
Military plating wastes	9711	Cd^{+2}			0.001		
Military sodium chromate	9711	$NaCrO_3^{-2}$			0.001		
Cooling tower blow-down		$NaCrO_3^{-2}$			0.001		

TABLE XIX - 7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Streams	Cost Range: $ per Physical Unit	Ref. No.
Organic aqueous solutions:							
Dimethyl sulfate prod. wastes	2611		11^{a,b}	90-99	0.01^{a}		See text
Acetaldehyde via ethylene oxidation	281				0.01		
Residue of ethylene dichloride and vinyl chloride	2821				0.01		
Nitrobenzene from rubber wastes	2822				0.01		
Synthetic fiber prod. wastes	2824				0.01		
Drug manufacture wastes	283				0.01		
Dye manufacturing wastes	2865				0.01		
Chlorinated hydrocarbon pesticide prod. wastes	287				0.01		
Organic herbicide prod. wastes	2879				0.01		
Organic phosphate pesticide production wastes	2879				0.01		

TABLE XIX-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Stream	Cost Range: \$ per Physical Unit	Ref. No.
Organic pesticide prod. wastes	2879		II[a]	90-99	0.01[b] (0.001)		See text
Phenoxy. herbicide prod. wastes	2879				0.01 (0.001)		
Nitrile pesticide wastes	2879				0.01 (0.001)		
Organic arsenicals from cacodylate. prod. wastes	2879				0.01 (0.001)		
Utilities and elect. station wastes	49				0.01 (0.001)		
Sludges:							
Arsenic from Cu refining flues	1021	As_2O_3, Hg^{+2}	111[a,b]	100	0.05		
Solvent based paint sludge	285	Pb^{+2}, Cr^{+6}, Cd^{+2}, CN			0.05		
Water based paint sludge	285	Cr^{+6}, Hg^{+2}			0.05		
Petroleum waste brine sludge	2911	Pb^{+2}, Hg^{+2}			0.05		
Iron prod. waste sludge	331	NaCN			0.05		
Arsenic trioxide from smelting	333	As_2O_2, Se			0.05		

TABLE XIX-7 (Cont.)

LIKELY POLLUTION TREATMENT PROCESSES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS

Item	SIC	Pollutant Treated	Treatment Process	Range in Efficiency (Percent)	Kg Residue (Dry) Per Kg Waste Stream	Cost Range: $ per Physical Unit	Ref. No.
Sludges: (Cont.)							
Battery manufact. waste sludge	3691	CD^{+2}, Ni^{+2}, Cu^{+2}, Pd^{+2}	III[a]	90-99	0.05		See text
Arsenic chloride from coal fuels	49	$AsCl_2$		100	0.05		
Military paris green	9711	Copper asceto-arsonite			0.05		
Radioactive wastes:							
Mill tailings	491	Radioactivity	Tailing ponds	90	1		
Conversion solids	491		Limestone neutralization	0.000004	1		
Gases from enrichment	491		None	0	n.a.		
Liquids from enrichment	491		Dilution	0	0		
Gases from fuel fabrication	491		None	0	n.a.		
Liquids from fuel fabrication	491		Dilution	100	0		

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[a] See Table XIX-6 for explanation of treatment process codes.

[b] Treatment residues excludes the weight of carbon, which is not estimatible and is always regenerated. Value in parenthesis is after incineration.

Radioactive wastes in the form of uranium mill tailings are normally separated in tailing ponds. The resulting tailings are stored in tailing piles: these residues present a hazard for many years after their initial creation. Figures XIX-3 and XIX-4 are examples of high and low-level storage facilities. The increasingly stringent pollution legislation will have two effects: more air filters will be used and smaller quantities of low-level liquids will be diluted and released. These quantities, however, are insignificant in relation to the mine tailings discussed,above. The quantities of filter media, sludges, and other solid wastes from nuclear power plants are presented in Section XVI.

In the cases of industry and government, the wide variation in methods and equipment makes a prediction of residues due to pollution controls difficult. The existence of these sources is noted and their waste streams are large, but the nuclear power industry's waste streams are significantly larger than the totals for all industry and government. Thus the quantity of radioactive waste from the nuclear power industry is close to the National total.

Reuse Potential for Solid Waste Residues.

The residues from incineration are generally not reusable. The resulting ash may be useful, but other sources of ash are more convenient and less likely to contain hazardous substances. Sludges from incineration are sometimes concentrated by evaporation and then disposed. Some sludges contain high concentrations of heavy metals. The increasing value of copper and nickel may make their recycling practical. This possibility will not decrease sludge volume, though, since only the heavy metals will be leached out, and the quantity of acid added to cause this leaching will compensate for this loss.

Radioactive wastes are not reused and will not be reused in the foreseeable future. The nuclear industry practices recycling of nuclear fuel to the extent that technology allows. Techniques for solidifying liquid radioactive wastes may reduce total waste volume significantly, but this does not affect net solid residues from pollution controls.

Total Impact on Solid Waste Residues of Pollution Treatment Processes.

The quantity of hazardous solid residues from pollution controls is very small compared to the quantity of non-hazardous wastes. This small amount is a significant factor in planning landfills, though, since these wastes require special handling and fill characteristics. Figure XIX-2 presents the flow diagram for these waste streams.

Tables XIX-8 through XIX-11 summarize the weights of hazardous residues from pollution control for 1971-1985. Treatment process codes were summarized in Table XIX-6. The residues are subtotaled for treatment group I applied to inorganic aqueous solutions, treatment group II applied to sludges, and various treatments applied to radioactive liquids. Table XIX-12 lists these totals. Notice that 1) not all hazardous residues

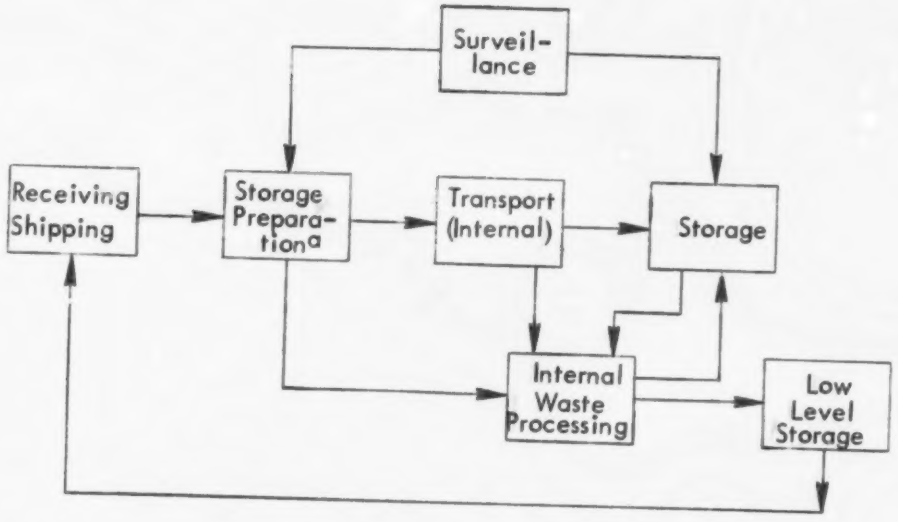
Surveil-lance
Receiving Shipping
Storage Preparation[a]
Transport (Internal)
Storage
Internal Waste Processing
Low Level Storage

FIGURE XIX-3
ACTIVITIES IN A RETRIEVABLE SURFACE STORAGE FACILITY FOR HIGH LEVEL RADIOACTIVE WASTE[237]

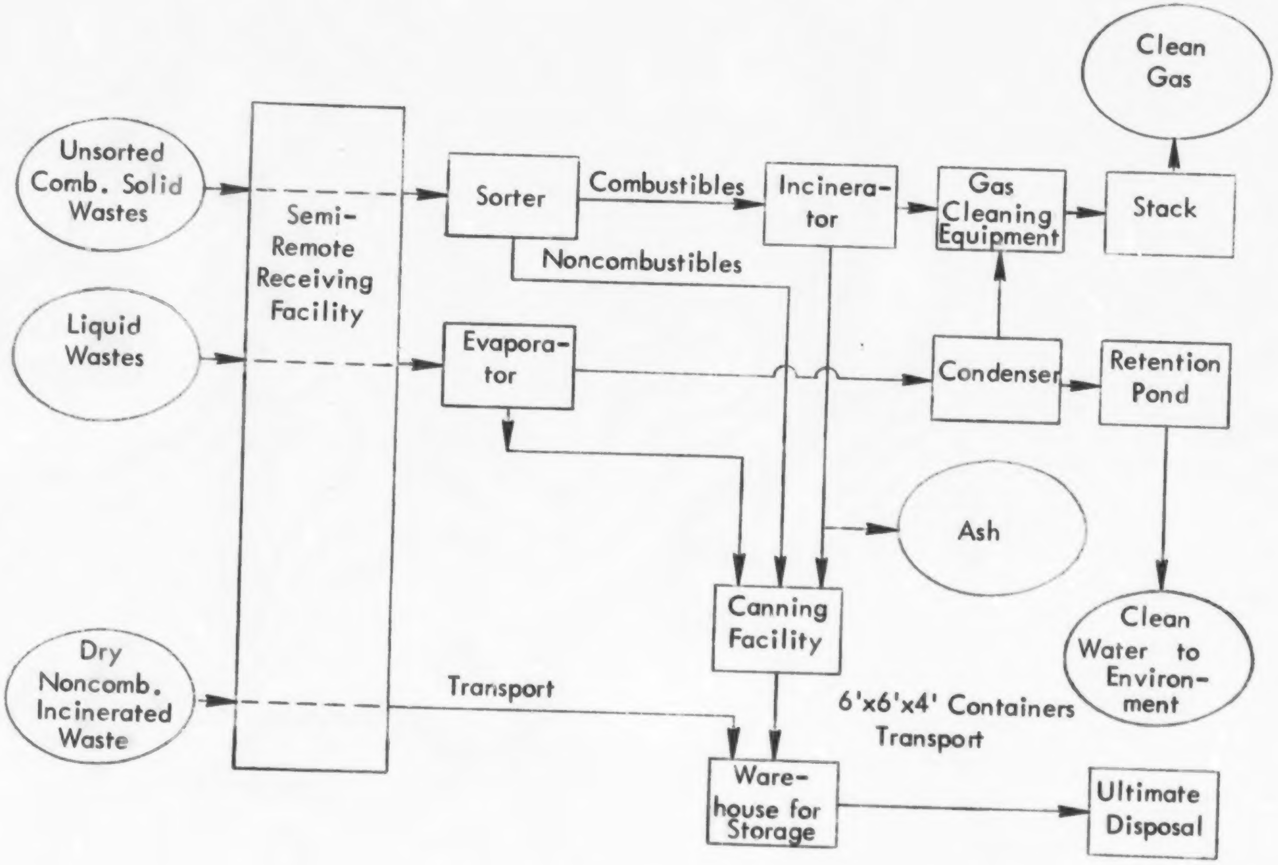
Unsorted Comb. Solid Wastes
Liquid Wastes
Dry Noncomb. Incinerated Waste
Semi-Remote Receiving Facility
Sorter
Combustibles
Noncombustibles
Evaporator
Transport
Incinerator
Gas Cleaning Equipment
Stack
Clean Gas
Condenser
Retention Pond
Clean Water to Environment
Ash
Canning Facility
6'x6'x4' Containers Transport
Warehouse for Storage
Ultimate Disposal

FIGURE XIX-4
TREATMENT PROCESS SCHEMATIC:
LOW-LEVEL RADIOACTIVE WASTES[232]

TABLE XIX-8
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS -1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions:								
Zinc ore acid wash	1031	I	50	n.d.	95		1	
Mercury ore extraction	1092		50	n.d.	95		1	
Cadmium ore waste	1099		50	45	95	43	1	0.43
Chromates from textile drying	22		50	4.5	95	4.3	0.5	0.02
Chlorine prod. waste	2812		50	25	95	24	0.5	1.2
Arsine prod. wastes	2813		50	0.003	95	0.003	0.5	0.00002
Pigment wastes	2816		50	n.d.	95		1	
Potassium chromate waste	2819		50	0.3	95	0.3	0.1	0.0003
Cyanide prod. waste	2819		100	n.d.	95		0.1	
Cellulose ester prod.	2821		50	10	95	9.5	0.5	0.05
Urethane prod. wastes	2821		50	n.d.	95		0.5	
Polycarbonate & polystyrene prod. wastes	2821		50	n.d.	95		0.5	
Wood preservative wastes	2865		50	n.d.	95		0.1	

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions: (Cont.)								
Hydrazine prod. wastes	2869	1	50	n.d.	95		0.1	
Agricultural chem. prod. wastes	287		100	n.d.	95		1.0	
Agricultural chem. intermediate wastes	287		50	0.05	95	0.05	1.0	0.0005
Ammonium sulfate prod. wastes	2873		50	0.0003	95	0.0003	0.1	0.0000003
Agricultural pesticide prod. arsenic wastes	2879		100	n.d.	95		0.5	
Mercury fungicide prod. wastes	2879		100	n.d.	95		0.5	
Pesticide arsonate wastes	2879		50	n.d.	95		0.5	
Pesticide arsenic wastes	2879		50	n.d.	95		0.5	
Petroleum wastes	291		50	20	95	19	0.5	0.1
Chrome tanning liquor	31		50	4.5	95	4.3	0.5	0.02
Mirror prod. wastes	3231		50	2	95	1.9	0.1	0.002
Cold finishing wastes	331		100	2000	95	1900	0.1	2
Consolidated steel wastes	331		100	200	95	190	0.1	0.2

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions: (Cont.)								
Stainless pickling liquor	3312	I	100	20	95	19	0.5	0.1
Brass mill wastes	333		100	20	95	19	0.1	0.02
Metal finishing wastes	33		50	10	95	9.5	0.1	0.01
Aluminum anodizing wastes	a		50	2	95	1.9	0.1	0.002
Brass plating wastes	a		50	n.d.	95		0.1	n.d.
Cadmium plating wastes	a		50	0.3	95	0.28	0.1	0.0003
Chrome plating wastes	a		50	n.d.	95		0.1	n.d.
Cyanide copper plating wastes	a		50	0.5	95	0.47	0.1	0.0005
Finishing effluents	a		50	n.d.	95		0.1	n.d.
Metal cleaning wastes	a		50	n.d.	95		0.1	n.d.
Plating preparation wastes	a		50	n.d.	95		0.5	n.d.
Silver plating wastes	a		50	n.d.	95		0.5	n.d.
Zinc plating wastes	a		50	n.d.	95		0.1	n.d.
Metal finishing chromic waste	34		50	10	95	9.5	0.1	0.01
Photography wastes	3555		50	0.001	95	0.0009	0.1	0.000001
Circuit manufacturing wastes	36		50	0.1	95	0.095	0.1	0.0001
Battery manufacturing wastes	36		50	n.d.	95		0.5	

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions: (Cont.)								
Aircraft plating wastes	372	I	50	10	95	9.5	0.5	0.05
Military plating wastes	9711		50	n.d.	95		0.1	
Military sodium chromate	9711		50	n.d.	95		0.1	
Cooling tower wastes	All		10	0.9	95	0.86	0.1	0.0009
		Total		2395.15				4.215
Aqueous organic solutions:								
Dimethyl sulfate prod. wastes	2611	II, III	50	0.05	100	0.05	1.0	0.0005
Acelaldehyde via ethylene oxidation	281		50	20	100	20	1.0	0.2
Residue of ethylene dichloride and vinyl chloride	2821		50	4.5	100	4.5	1.0	0.05
Nitrobenzene from rubber wastes	2822		50	1000.	100	1000	1.0	10
Synthetic fiber prod. wastes	2824		50	n.d.	100		1.0	
Drug manufacture wastes	283		50	1000	100	1000	1.0	10
Dye manufacture wastes	2865		50	n.d.	100		1.0	

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous organic solutions: (Cont.)								
Chlorinated hydrocarbon pesticide wastes	2879	II, III	100	90	100	90	1.0	0.9
Organic herbicide prod. wastes	2879		100	200	100	200	1.0	2
Organic phosphate pesticide wastes	2879		100	30	100	30	1.0	0.3
Organic pesticide prod. wastes	2879		100	100	100	100	1.0	1.0
Phenoxy herbicide prod. wastes	2879		100	20	100	20	1.0	0.2
Nitrilo-pesticide wastes	2879		100	n.d.	100		1.0	
Organic arsonicals from cacodylate	2879		50	n.d.	100		1.0	
Utilities and electric station wastes	49		10	1	100	1	1.0	0.01
Subtotal before incineration[b]								24.66
Subtotal after incineration[c]								20
Sludges:								
Arsenic wastes from copper refining flues	1021	III	100	40	100	40	5	2

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Sludges: (Cont.)								
Solvent-based paint sludge	285	III	100	40	100	40	5	2
Water-based paint sludge	285		100	30	100	30	5	1.5
Petroleum brine waste sludge	2911		100	4	100	4	5	0.2
Iron prod. waste sludge	331		100	6	100	6	5	0.3
Arsenic trioxide from smelting	333		100	20	100	20	5	1.
Battery manufacture waste	3691		100	50	100	50	5	2.5
Arsenic trichloride from coal	49		100	6	100	6	5	0.3
Military paris green	9711		100	0.03	100	0.03	5	0.0015
Subtotal								9.8015
Radioactive wastes:								
Mill tailing	491	Tailing ponds	100	1,100	90	990	100	990
Conversion aqueous wastes	491	Limestone, neutralization	100	270	100	270	0.0004	0.11
Gases from enrichment	491	None	0	0	0	0	100	0

TABLE XIX-8 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1971

				Weight in Kg x 10^6				
Pollutant: Item	SIC	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Radioactive wastes: (Cont.)								
Liquids from enrichment	491	Dilution	100	0.0003	100	0.0003	0	0
Gases from fuel fabrication	491	None	0	0	0	0	100	0
Liquids from fuel fabrication	491	Dilution	100	10	100	10	0	0
Solid residues from fuel enrichment	d							0.73
Subtotal								990.84
Total hazardous residues:								1,029.4

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[a] These items are summed in SIC 33 - metal finishing wastes.

[b] Subtotal before incineration excludes regenerated carbon.

[c] 20 percent of residue assumed incinerated. Non-hazardous ash from incineration, not included in total residues, is approximately 1 x 10^6 kg.

[d] See Section XVI on electric power generation for the method used for calculating this value.

TABLE XIX-9
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions:								
Zinc ore acid wash	1031	I	50	n.d.	95		1.0	
Mercury ore extraction	1092		50	n.d.	95		1.0	
Cadmium ore waste	1099		50	55	95	52	1.0	0.52
Chromates from textile drying	22		50	5.5	95	5.2	0.5	0.03
Chlorine prod. waste	2812		50	30	95	28.5	0.5	0.14
Arsine prod. wastes	2813		50	0.003	95	0.003	0.5	0.000014
Pigment wastes	2816		50	n.d.	95		1.0	
Potassium chromate waste	2819		50	0.3	95	0.28	0.1	0.0003
Cyanide prod. wastes	2819		100	n.d.	95		0.1	
Cellulose ester prod.	2821		50	15	95	14.2	0.5	0.071
Urethane prod. wastes	2821		50	n.d.	95		0.5	
Polycarbonate & polystyrene prod. wastes	2821		50	n.d.	95		0.5	
Wood preservative wastes	2865		50	n.d.	95		0.1	
Hydrozine prod. wastes	2869		50	n.d.	95		0.1	

TABLE XIX-9 (Cont.)

TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Agricultural chem. prod. wastes	287	I	100	n.d.	95			
Agricultural chem. intermediate wastes	287		50	0.055	95	0.052		0.00052
Ammonium sulfate prod. wastes	2873		50	0.0003	95	0.00028	0.1	0.000003
Agricultural pesticide prod. arsenic wastes	2879		100	n.d.	95		0.5	
Mercury fungicide prod. wastes	2879		100	n.d.	95		0.5	
Pesticide arsonate wastes	2879		50	n.d.	95		0.5	
Pesticide arsenic wastes	2879		50	n.d.	95		0.5	
Petroleum wastes	291		50	25	95	24	0.5	0.12
Chrome tanning liquor	31		50	5	95	4.75	0.5	0.024
Mirror production wastes	3231		50	2.5	95	2.37	0.1	0.0023
Cold finishing wastes	331		100	3000	95	2850	0.1	2.85
Consolidated steel wastes	331		100	300	95	285	0.1	0.285
Stainless pickling liquor	3312		100	30	95	28.5	0.5	0.142

TABLE XIX-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Brass mill wastes	333	I	100	20	95	19	0.1	0.019
Metal finishing wastes	33		50	15	95	14.2	0.1	0.01
Aluminum anodizing wastes	a		50	2.5	95	2.38	0.1	0.002
Brass plating wastes	a		50	n.d.	95		0.1	
Cadmium plating wastes	a		50	0.4	95	0.33	0.1	0.0003
Chrome plating wastes	a		50	n.d.	95		0.1	
Cyanide copper plating wastes	a		50	0.6	95	0.6	0.1	0.0006
Finishing effluents	a		50	n.d.	95		0.1	
Metal cleaning wastes	a		50	n.d.	95		0.1	
Plating preparation wastes	a		50	n.d.	95		0.5	
Silver plating wastes	a		50	n.d.	95		0.5	
Zinc plating wastes	a		50	n.d.	95		0.1	
Metal finishing chromic acid	34		50	10	95	9.5	0.1	0.0009
Photography wastes	3555		50	0.002	95	0.002	0.1	0.000002
Circuit manufacturing wastes	36		50	0.2	95	0.2	0.1	0.0002
Battery manufacturing wastes	36		50	n.d.	95		0.5	
Aircraft plating wastes	372		50	15	95	14.2	0.5	0.07

TABLE XIX-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Military plating wastes	9711	I	50	n.d.	95		0.1	
Military sodium chromate	9711		50	n.d.	95		0.1	
Cooling tower wastes	All		10	1.2	95	1.1	0.1	0.0011
Subtotal								4.29
Aqueous organic solutions:								
Dimethyl sulfate prod. wastes	2611	II,III	50	0.06	100	0.06	1	0.0006
Acetaldehyde via ethylene oxidation	281		50	25	100	25	1	0.25
Residue of ethylene dichloride and vinyl chloride	2821		50	6.5	100	6.5	1	0.07
Nitrobenzene from rubber wastes	2822		50	1500	100	1500	1	15
Synthetic fiber prod. wastes	2824		50	n.d.	100		1	
Drug manufacture wastes	283		50	1500	100	1500	1	15
Dye manufacture wastes	2865		50	n.d.	100		1	
Chlorinated hydrocarbon pesticide wastes	2879		100	110	100	110	1	1.1

TABLE XIX-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Organic herbicide prod. wastes	2879	II, III	100	200	100	200	1	2.0
Organo- phosphate pesticide wastes	2879		100	40	100	40	1	0.4
Organic pesticide prod. wastes	2879		100	120	100	120	1	1.2
Phenoxy herbicide prod. wastes	2879		100	20	100	20	1	0.2
Nitrilo-pesticide wastes	2879		100	n.d.	100			
Organic arsonicals from cacodylate prod.	2879		50	n.d.	100		1	
Utilities and electric station wastes	49		10	1	100	1	1	0.01
Subtotal before incineration[b]								35.23
Subtotal after incineration[c]								21
Sludges:								
Arsenic wastes from copper refining flues	1021	III	100	50	100	50	5	2.5
Water-based paint sludge	285		100	40	100	40	5	2
Solvent-based paint sludge	285		100	50	100	50	5	2.5
Petroleum brine waste sludge	2911		100	5	100	5	5	0.25
Iron prod. waste sludge	331		100	8	100	8	5	0.4

TABLE XIX-9 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1975

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Arsenic trioxide from smelting	333	III	100	30	100	30	5	1.5
Battery manufacture waste	3691		100	70	100	70	5	3.5
Arsenic trichloride from coal	49		100	8	100	8	5	0.4
Military paris green	9711		100	0.03	100	0.03	5	0.0015
Subtotal								13.05
Radioactive wastes:								
Mill tailing	491	Tailing ponds	100	6,600	90	5,940	100	5,940
Conversion aqueous wastes	491	Limestone neutralization	100	1,600	100	1,600	0.0004	0.0064
Gases from enrichment	491	None	n.d.	0	0	0	100	0
Liquids from enrichment	491	Dilution	100	0.0002	100	0.0002	0	0
Gases from fuel fabrication	491	None	n.d.	0	0	0	100	0
Liquids from fuel fabrication	491	Dilution	100	0.0002	100	60	0	0
Solid residues from fuel enrichment[d]								4.3
Subtotal								5,944.3
Total hazardous residues:								5,982.64

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[a] These items are summed in SIC 33 - metal finishing wastes. [b] Subtotal before incineration excludes regenerated carbon.

[c] 40 percent of residues assumed incinerated. Non-hazardous ash from incineration, not included in total residues, is approximately 1.4 x 10^6 kg.

[d] See Section XVI on electric power generation for the method used for calculating this value.

TABLE XIX-10
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1980

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions:								
Zinc ore acid wash water	1031	I	75	n.d.	95		1.0	
Mercury ore extraction	1092		75	n.d.	95		1.0	
Cadmium ore waste	1099		75	97.5	95	92.6	1.0	0.93
Chromates from textile drying	22		75	9.75	95	9.3	0.5	0.05
Chlorine prod. waste	2812		75	60	95	57	0.5	0.28
Ansine prod. wastes	2813		75	0.005	95	0.0042	0.5	0.00002
Pigment wastes	2816		75	n.d.	95		1.0	
Potassium chromate waste	2819		75	0.6	95	0.57	0.1	0.0006
Cyanide prod. wastes	2819		100	n.d.	95		0.1	
Cellulose ester prod.	2821		75	30	95	28.5	0.5	0.14
Urethane prod. wastes	2821		75		95		0.5	
Polycarbonate, polystyrene prod. wastes	2821		75	n.d.	95		0.5	
Wood preservative wastes	2865		75	n.d.	95		0.1	
Hydrazine prod. wastes	2869		75	n.d.	95		0.1	
Agricultural chemical prod. wastes	287		100	n.d.	95		1.0	
Agricultural chemical intermediate wastes	287		75	0.1	95	0.095	1.0	0.001
Ammonium sulfate prod. wastes	2873		75	0.0005	95	0.0005	0.1	0.0000005

TABLE XIX-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS – 1980

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Agricultural pesticide prod. arsenic wastes	2879	I	100	n.d.	95		0.5	
Mercury fungicide prod. wastes	2879		100	n.d.	95		0.5	
Pesticide arsonate wastes	2879		75	n.d.	95		0.5	
Pesticide arsenic wastes	2879		75	n.d.	95		0.5	
Petroleum wastes	291		75	37.5	95	35.6	0.5	0.2
Chrome tanning liquor	31		75	7.5	95	7.12	0.5	0.04
Mirror prod. wastes	3231		75	4.5	95	4.275	0.1	0.005
Cold finishing wastes	331		100	3,000	95	2,850	0.1	3
Consolidated steel wastes	331		100	300	95	285	0.1	0.3
Stainless pickling liquor	3312		100	30	95	28.5	0.5	0.15
Brass mill wastes	333		100	30	95	28.5	0.1	0.03
Metal finishing wastes	33		75	22.5	95	21.4	0.1	0.02
Aluminum anodizing wastes	a		75	4.5	95	4.275	0.1	0.004
Brass plating wastes	a		75	n.d.	95		0.1	
Cadmium plating wastes	a		75	0.6	95	0.57	0.1	0.0006
Chrome plating wastes	a		75	n.d.	95		0.1	
Cyanide copper plating wastes	a		75	1.05	95	1.0	0.1	0.001
Finishing effluents	a		75	n.d.	95		0.1	
Metal cleaning wastes	a		75	n.d.	95		0.1	
Plating preparation wastes	a		75	n.d.	95		0.5	
Silver plating wastes	a		75	n.d.	95		0.5	
Zinc plating wastes	a		75	n.d.	95		0.1	

TABLE XIX-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1980

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Metal finishing chromic acid	34	I	75	22.5	95	21.4	0.1	0.02
Photography wastes	3555		75	0.002	95	0.0019	0.1	0.000002
Circuit manufacturing wastes	36		75	0.3	95	0.285	0.1	0.00003
Battery manufacturing wastes	36		75	n.d.	95		0.5	
Aircraft plating wastes	372		75	30	95	28.5	0.5	0.14
Military plating wastes	9711		75	n.d.	95		0.1	
Military sodium chromate	9711		75	n.d.	95		0.1	
Cooling tower wastes	All		20	2.8	95	2.7	0.1	0.003
								5.315
Aqueous organic solutions:								
Dimethyl sulfate prod. wastes	2611	II, III	75	0.1	100	0.1	1	0.001
Acetaldehyde via ethylene oxidation	281		75	45	100	45	1	0.45
Residue of ethylene dichloride and vinyl chloride	2821		75	14.25	100	14.25	1	0.14
Nitrobenzene from rubber wastes	2822		75	3,000	100	3,000	1	30
Synthetic fiber prod. wastes	2824		75	n.d.	100		1	
Drug manufacture wastes	283		75	3,000	100	3,000	1	30
Dye manufacture wastes	2865		75	n.d.	100		1	
Chlorinated hydrocarbon pesticide wastes	2879		100	130	100	130	1	1.3

TABLE XIX-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS – 1980

				Weight in Kg x 10^6				
Pollutant: Item	SIC	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Organic herbicide prod. wastes	2879	II, III	100	300	100	300	1	3
Organo-phosphate pesticide wastes	2879		100	40	100	40	1	0.4
Organic pesticide prod. wastes	2879		100	150	100	150	1	1.5
Phenoxy herbicide prod. wastes	2879		100	30	100	30	1	0.3
Nitrite pesticide wastes	2879		100	n.d.				
Organic arsonicals from cacodylate prod.	2879		75	n.d.	100		1	
Utilities and electric station wastes	49		20	4	100	4	1	0.04
Subtotal before incineration[b]								67.13
Subtotal after incineration[c]								27
Sludges:								
Arsenic wastes from copper refining flues	1021	III	100	60	100	60	5	3
Solvent-based paint sludge	285		100	50	100	50	5	2.5
Water-based paint sludge	285		100	40	100	40	5	2
Petroleum brine waste sludge	2911		100	5	100	5	5	0.25
Iron prod. waste sludge	331		100	9	100	9	5	0.45
Arsenic trioxide from smelting	333		100	30	100	30	5	1.5

TABLE XIX-10 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1980

Pollutant: Item	SIC		% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Battery manufacture waste	3691	III	100	90	100	90	5	4.5
Arsenic trichloride from coal	49		100	11	100	11	5	0.6
Military paris green	9711		100	0.04	100	0.04	5	0.002
Subtotal								14.8
Radioactive wastes:								
Mill tailing	491	Tailing ponds	100	18,000	90	16,200	100	16,202
Conversion aqueous wastes	491	Limestone neutralizing	100	4,500	100	4,500	0.0004	
Gases from enrichment	491	None	--	0	0		100	0
Liquids from enrichment			100	0.005	100	0.005	0	0
Gases from fuel fabrication	491	None	--	0	0		100	0
Liquids from fuel fabrication	491	Dilution	100	160	100	160	0	0
Solid residues from fuel enrichment[d]	491							12
Subtotal								16,214
Total hazardous residues:								16,261.11

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[a] These items are summed in SIC 33 - metal finishing wastes. [b] Subtotal before incineration excludes regenerated carbon.

[c] 60 percent of residues assumed incinerated. Non-hazardous ash from incineration, not included in total residues, is approximately 4 x 10^6 kg.

[d] See Section XVI on electric power generation for the method used for calculating this value.

TABLE XIX-11

TOTAL IMPACT OF POLLUTION TREATMENT
PROCESSES ON SOLID WASTE RESIDUES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1985

				Weight in Kg x 10^6				
Pollutant: Item	SIC	Treatment Process	% Treated by Process	Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions:								
Zinc ore acid wash	1031	I	75	n.d.	95		1	
Mercury ore extraction	1092		75	n.d.	95		1	
Cadmium ore waste	1099		75	112.5	95	106.9	1	1.07
Chromates from textile drying	22		75	11.25	95	10.7	0.5	0.053
Chlorine prod. waste	2812		75	75	95	71.2	0.5	0.35
Arsine prod. wastes	2813		75	0.008	95	0.0072	0.5	0.00004
Pigment wastes	2816		75	n.d.	95		1	
Potassium chromate wastes	2819		75	0.75	95	0.72	0.1	0.0007
Cyanide prod. wastes	2819		100	n.d.	95		0.1	
Cellulose ester prod.	2821		75	45	95	42.8	0.5	0.2
Urethane prod. wastes	2821		75	n.d.	95		0.5	
Polycarbonate, polystyrene prod. wastes	2821		75	n.d.	95		0.5	
Wood preservative wastes	2865		75	n.d.	95		0.1	
Hydrazine prod. wastes	2869		75	n.d.	95		0.1	
Agricultural chemical prod. wastes	287		100	n.d.	95		1	
Agricultural chemical intermediate wastes	287		75	0.11	95	0.104	1	0.001
Ammonium sulfate prod. wastes	2873		75	0.0006	95	0.00057	0.1	0.0000006
Agricultural pesticide prod. arsenic wastes	2879		100	n.d.	95		0.5	

TABLE XIX-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1985

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions: (Cont.)								
Mercury fungicide prod. wastes	2879	I	100	n.d.	95		0.5	
Pesticide arsonate wastes	2879		75	n.d.	95		0.5	
Pesticide arsenic wastes	2879		75	n.d.	95		0.5	
Petroleum wastes	291		75	45	95	42.8	0.5	0.2
Chrome tanning liquor	31		75	8.25	95	7.8	0.5	0.04
Mirro prod. wastes	3231		75	6	95	5.7	0.1	0.006
Cold finishing wastes	331		100	3,000	95	2,850.0	0.1	3
Consolidated steel wastes	331		100	300	95	285.0	0.1	0.3
Stainless pickling liquor	3312		100	30	95	28.5	0.5	0.15
Brass mill wastes	333		100	30	95	28.5	0.1	0.03
Metal finishing wastes	33		75	22.5	95	21.4	0.1	0.02
Aluminum anodizing wastes	a		75	5.25	95	4.98	0.1	0.005
Brass plating wastes	a		75	n.d.	95		0.1	
Cadmium plating wastes	a		75	0.675	95	0.65	0.1	0.0007
Chrome plating wastes	a		75	n.d.	95		0.1	
Cyanide copper plating wastes	a		75	1.2	95	1.14	0.1	0.0011
Finishing effluents	a		75	n.d.	95		0.1	
Metal cleaning wastes	a		75	n.d.	95		0.1	
Plating preparation wastes	a		75	n.d.	95		0.5	
Silver plating wastes	a		75	n.d.	95		0.5	
Zinc plating wastes	a		75	n.d.	95		0.1	
Metal finishing chromic acid	34		75	22.5	95	21.4	0.1	0.02

TABLE XIX-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES
FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1985

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6 Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous inorganic solutions:	(Cont.)							
Photography wastes	3555	I	75	0.003	95	0.0028	0.1	0.00003
Circuit manufacturing wastes	36		75	0.4	95	0.38	0.1	0.0004
Battery manufacturing wastes	36		75	n.d.	95		0.5	
Aircraft plating wastes	372		75	30	95	28.5	0.5	0.15
Military plating wastes	9711		75	n.d.	95			
Military sodium chromate	9711		75	n.d.	95			
Cooling tower wastes	All		50	8.5	95	8.1		0.008
Subtotal								5.61
Aqueous organic solutions:								
Dimethyl sulfate prod. wastes	2611	II,III	75	0.11	100	0.11	1	0.0011
Acetaldehyde via ethylene oxidation	281		75	60	100	60	1	0.6
Residue of ethylene dichloride and vinyl chloride	2821		75	20.25	100	20.25	1	0.2
Nitrobenzene from rubber wastes	2822		75	4,500	100	4,500	1	45
Synthetic fiber prod. wastes	2824		75	n.d.	100		1	
Drug manufacture wastes	283		75	4,500	100	4,500	1	45
Dye manufacture wastes	2865		75	n.d.	100		1	
Chlorated hydrocarbon pesticide wastes	2879		100	150	100	150	1	1.5
Organic herbicide prod. wastes	2879		100	300	100	300	1	3

TABLE XIX-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS - 1985

Pollutant: Item	SIC	Treatment Process	% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous organic solutions: (Cont.)								
Organo-phosphate pesticide wastes	2879	II, III	100	50	100	50	1	0.5
Organic pesticide prod. wastes	2879		100	170	100	170	1	1.7
Phenoxy herbicide prod. wastes	2879		100	30	100	30	1	0.3
Nitrilo-pesticide wastes	2879		100	n.d.	100		1	
Organic arsonicals from cacodylate prod.	2879		75	n.d.	100		1.	
Utilities and electric station wastes	49		20	4	100	4	1	0.04
Subtotal before incineration[b]								200
Subtotal after incineration[c]								97.8
Sludges:								
Arsenic wastes from copper refining flues	1021	III	100	70	100	70	5	3.5
Solvent-based paint sludge	285		100	60	100	60	5	3
Water-based paint sludge	285		100	40	100	40	5	2
Petroleum brine waste sludge	2911		100	6	100	6	5	0.3
Iron prod. waste sludge	331		100	10	100	10	5	0.5
Arsenic trioxide from smelting	333		100	40	100	40	5	2
Battery manufacture waste	3691		100	120	100	120	5	6
Arsenic trichloride from coal	49		100	14	100	14	5	0.7

TABLE XIX-11 (Cont.)
TOTAL IMPACT OF POLLUTION TREATMENT PROCESSES ON SOLID WASTE RESIDUES FOR INDUSTRIES GENERATING HAZARDOUS WASTE STREAMS – 1985

Pollutant: Item	SIC		% Treated by Process	Weight in Kg x 10^6				
				Solid Residues @100% Eff.	Actual % Treatment Efficiency	Net Solid Residues	% Not Reused	Solid Waste Residues
Aqueous organic solutions: (Cont.)								
Military paris green	9711	III	100	0.04	100	0.04	5	0.002
Subtotal								18
Radioactive wastes:								
Mill tailing	491	Tailing ponds	100	33,000	90	29,700	100	29,700
Conversion aqueous wastes	491	Limestone, neutralization	100	8,500	100	8,500	0.0004	3.4
Gases from enrichment	491	None	0	0	0	0	100	0
Liquids from enrichment	491	Dilution	100	0.01	100	0.01	0	0
Gases from fuel fabrication	491	None	0	0	0	0	100	0
Liquids from fuel fabrication	491	Dilution	100	300	100	300	0	0
Solid residues from fuel enrichment[d]	491							23
Subtotal								29,726.4
Total hazardous residues:								29,770

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[a] These items are summed in SIC 33 – metal finishing wastes.

[b] Subtotal before incineration excludes regenerated carbon.

[c] 80 percent of residues assumed incinerated. Non-hazardous ash from incineration, not included in total residues, is approximately 8.6 x 10^6 kg.

[d] See Section XVI on electric power generation for the method used for calculating this value.

TABLE XIX-12

TOTAL HAZARDOUS RESIDUES FROM POLLUTION CONTROLS

	10^6 kg (10^3 metric tons)			
Hazaradous solids from:	1971	1975	1980	1985
Inorganic solutions	3.1	4.5	5.5	5.8
Organic solutions	20[a]	21[a]	27[a]	22[a]
Sludges	9.8	13	15	18
Total non-radioactive	33	39	48	46
Total radioactive	1,000[b] + 0.73[c]	6,000[b] + 4.3[c]	16,000[b] + 12[c]	30,000[b] + 23[c]

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[a] Estimates increasing uses of incineration to regenerate carbon, and increased uses of carbon absorption over use of evaporation.

[b] Radioactive mill tailings presently impounded in basins and isolated from groundwater.

[c] Radioactive solid residues from rest of nuclear power cycle.

streams were found, and 2) not all the identified streams have annual quantity data. Thus, the total hazardous residues are underestimated perhaps by as much as 100 percent, but more likely approximately 50 percent. These residues are salts of heavy metals, organic solids, and radioactive elements. In some residues large fractions of non-hazardous residues will also reside. EPA has initiated specific studies of each industry in order to obtain detailed data on waste composition; these studies are necessary since the National stream is the sum total of many distinct and different industries.

The effect of incineration is to eliminate hazardous organics by oxidation. Tables XIX-8 through XIX-11 indicate an increasing estimated use of incineration. First, carbon absorption will be used more often so that regeneration of carbon will use thermal or steam treatments. Second, improved technology for incinerators will make higher use of thermal versus steam. These combined effects are hard to estimate, so a linear progression 20, 40, 60, 80 is used. Otherwise, the use of carbon absorption or evaporation makes no difference regarding quantity of solid residues.

Factors Affecting Quality of Data.

The list of hazardous wastes compiled in this Section is incomplete under the definition of hazardous wastes. The economic data on production are much more accurate than other data used to estimate solid residues. The pollution quantity predictions require the assumption of no significant changes in hazardous waste generation rate and composition before 1985. The treatment methods listed are very likely to be used, as other applicable methods are experimental, costly, and unreliable. Solid residues generation is a broad estimate because very little data on composition are available. The estimates of solids content are estimates based on chemical solubility limits and technological state-of-the-art limits. At this stage, variance in individual hazardous waste stream values is large, but the average of the large number of independent streams tends to bring the total estimate nearer to the true average.

Summary.

Untreated Discharges. The limited nature of the data in this Section made it impossible to derive the dry weights of the hazardous wastes streams in all cases. The largest growth in production of non-radioactive hazardous waste streams in the air or water through 1985 is projected to be from inorganic chemicals, synthetics, drugs, organic chemicals, industrial machinery, electrical machinery, aircraft, and power utilities. The discharges were separated into aqueous inorganic solutions, aqueous organic solutions, sludges, and radioactive wastes. The tailings from uranium mining, because of their radioactivity and their huge mass, are the largest single source of hazardous waste streams. Because of the extremely diverse nature of these waste streams, no general statements can be made as to their make up. All the waste streams included in this Section are damaging far out of proportion to their mass in relation to other common pollutants.

Treatment Methods and Reuse. Non-radioactive hazardous wastes are subject to few controls at the present but will require many diverse treatments by 1985. Because of the small percentage of hazardous wastes from air pollution control, discussion focused on water pollution control processes for hazardous waste streams. Air pollution controls mainly consist of baghouses, and electrostatic precipitators to capture evaporated and particulate hazardous pollutants such as arsenic in refinery flues. Advanced water treatment will be necessary as the evaporation ponds presently in wide use are prohibited by law. Neutralization and chemical precipitation will drop heavy metals from solution while oxidation is used for cyanide and other pollutants. Liquid-solids separation may be achieved by sedimentation/floculation. Carbon absorption is an increasingly popular method for removal of organics from water, which may also be accomplished by oxidation by chlorine, ozone, potassium permanganate, or peroxide. Special treatments such as ammonia stripping are required for some wastes, but these are of secondary interest. The residues from hazardous waste treatment and disposal are generally not reusable. Some sludges, however, contain high concentrations of heavy metals for which the increasing value of copper and nickel may make their recycling practical. Radioactive wastes from air and water pollution control are not reused and will not be reused in the foreseeable future. The reprocessing of spent fuel rods in nuclear power plants is a common practice but cannot be termed an air or water pollution control. Most radioactive wastes are solidified and held for long-term disposal. The radioactive tailings from uranium mines are separated from the mine or mill process water and held in tailings piles indefinitely.

Residues Generated from Pollution Control: Types and Amounts. The total hazardous solid waste residues from air and water pollution controls were projected to increase from 1,030 million kg in 1971 to 29,770 million kg in 1985. Well over 99 percent of this increase is attributable to the increased amounts of uranium tailings from uranium mines. Uranium tailing quantities were forecast to increase from approximately 1,000 million kg in 1971 to approximately 30,000 million kg in 1985, a thirty-fold increase. Quantities of other hazardous solid residues derived from pollution control, in contrast, are much smaller in absolute value and show a much slower rate of increase between 1971 and 1985. Hazardous solid residues from inorganic and organic residues plus those from sludges were estimated to be approximately 33 million kg in 1971, to peak at 37.5 million kg in 1980, and to decline to approximately 36 million kg by 1985.

Non-radioactive hazardous solid residues, although of minor importance compared to radioactive hazardous solid residues in terms of weight, nevertheless present significant handling and disposal problems. In California, a landfill classification system is in effect which classifies those landfill sites environmentally suitable for hazardous waste disposal; this system is a promising method for informing hazardous waste generators where wastes may be properly disposed. Unfortunately, recent regulations have caused industrial confusion concerning acceptable disposal alternatives, resulting in the dangerous practice of storing hazardous residues on-site until disposal alternatives are further clarified.

SECTION XX
SUMMARY: TOTAL NATIONAL IMPACT OF POLLUTION CONTROLS ON SOLID WASTE MANAGEMENT

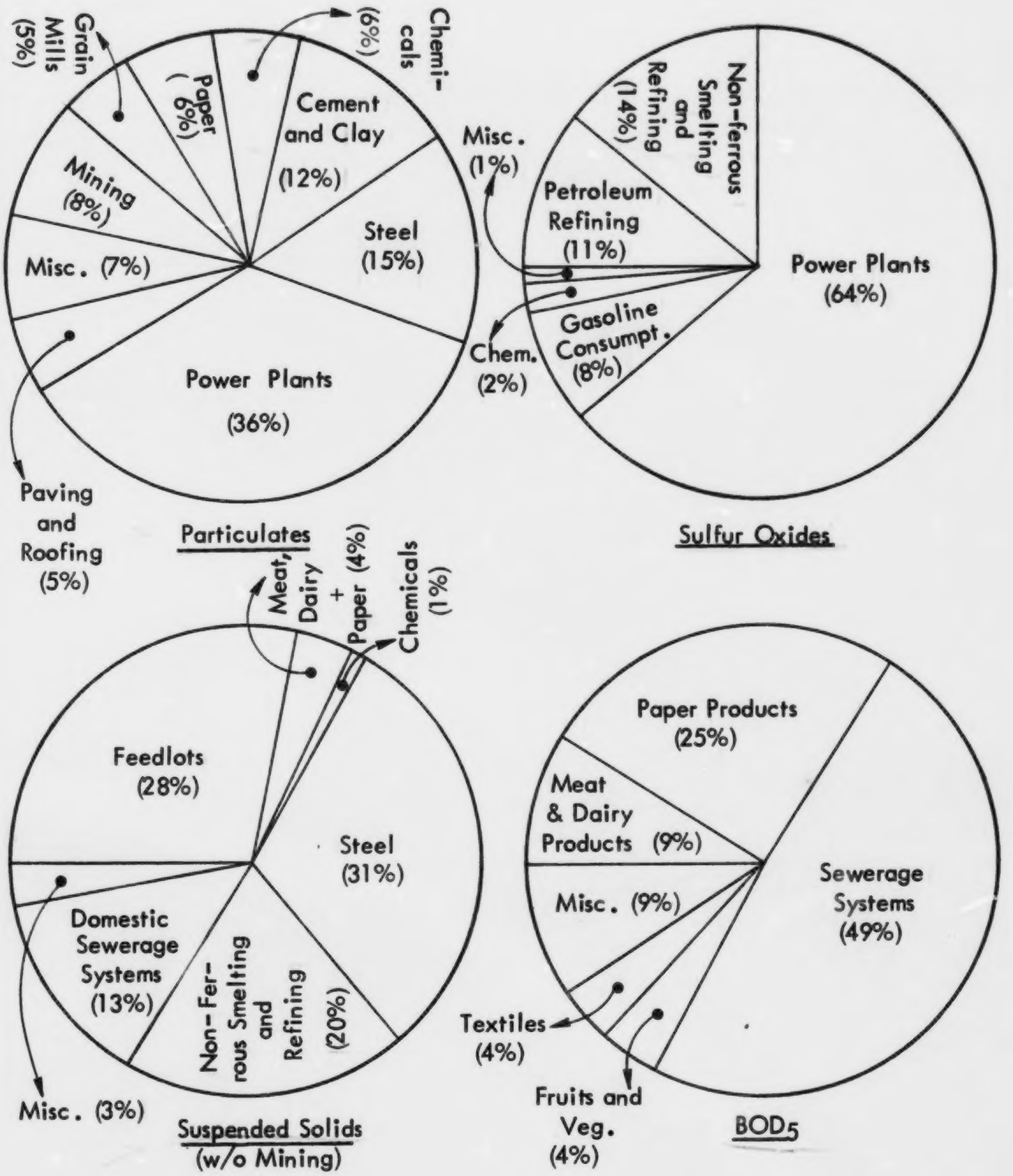
Uncontrolled National Discharges of Air and Water Pollutants Important in Solid Waste Generation.

Figure XX-1 presents the estimated 1971 breakdown by industrial source of National discharges before treatment of air and water pollutants capable of generating solid waste residues from control activities. Appendices A and B list in greater detail assumptions behind these uncontrolled discharge estimates. It is clear from Figure XX-1 that very few sectors were responsible for the majority of uncontrolled pollutant emissions. Mining, grain mills, paper products, chemicals, cement and clay, steel production, and steam electric power plants contributed 88 percent of all particulate emissions before treatment in 1971, with power plants alone contributing 36 percent. Petroleum refining, nonferrous smelting and refining, and power plants contributed 89 percent of all sulfur oxide emissions, with power plants alone contributing 64 percent. For water pollutants, the basic steel and feedlot industries contributed 59 percent of suspended solids, while sewerage systems and paper and pulp plants contributed 74 percent of the BOD_5 discharges accounted for in this study. Tables XX-1 and XX-2 list uncontrolled National discharges of air and water pollutants, respectively, for all industrial sectors evaluated from 1971 through 1985. As shown by these tables, the industries that were major dischargers in 1971 were generally forecast to remain major dischargers through 1985. Discharges for all industries before control were forecast to increase between 1971 and 1985, due largely to economic growth.

Major Sectors Generating Solid Wastes from Air and Water Pollution Control.

Table XX-3 and Figure XX-2 summarize the solid wastes estimated to result from air and water pollution controls in major American industries. For the years 1971 through 1985, these solid wastes were projected to increase from 60,700 million kg in 1971 to 244,300 million kg in 1985. Mine tailing wastes were excluded from the totals, since, although very large in quantity, they also are disposed of in the general locale of the mines and are normally not a part of the urban landfill disposal system. In the case of strip mines, the solid residues may be used in reclaiming the land.

It is clear from Table XX-3 that power plants play a major role in the generation of solid waste by pollution control activities. After treatment and reuse of the residues, power plant solid wastes from air and water pollution control were projected to increase from 25,600 million kg in 1971 to 135,550 million kg in 1985. Power plants contributed 42 percent of all solid wastes from air and water pollution control in 1971, and this should increase to 55 percent by 1985. The major factor in this increase will be the use of limestone scrubbers to control sulfur oxides. If another practical method of controlling SO_x is devised which eliminates the solid residues yielded by limestone scrubbing, or if these residues can be reclaimed, the solid wastes projected in 1985 would decrease to 54,220 million kg, about 40 percent of the amount originally projected for that year.



Particulates

Sulfur Oxides

Suspended Solids (w/o Mining)

BOD_5

FIGURE XX-1
INDUSTRIAL SECTORS
CONTRIBUTING TO NATIONAL
DISCHARGES OF MAJOR
AIR AND WATER POLLUTANTS
1971

TABLE XX-1

DISCHARGE INVENTORY BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE RESIDUES WHEN TREATED-10^6 KG PER YEAR

SIC	Description	Particulates 1971	Particulates 1975	Particulates 1980	Particulates 1985	Sulfur Oxides 1971	Sulfur Oxides 1975	Sulfur Oxides 1980	Sulfur Oxides 1985
Major Sources									
10-12,14	Mining	8,000	9,400	11,200	13,100	-	-	-	-
203	Canned and preserved fruits and vegetables	0.74	0.92	1.13	1.31	-	-	-	-
204	Grain mills	4,870	5,590	6,640	7,880	-	-	-	-
26	Paper and allied products	5,380	6,500	7,750	9,080	n.d.	n.d.	n.d.	n.d.
28	Chemicals and allied products	5,840	6,670	7,860	9,280	530	670	870	1,110
13, 291	Petroleum refining, extraction and trans.	300	330	380	430	3,480	3,820	4,340	4,990
324-326	Cement and clay	10,910	12,230	13,970	15,920	-	-	-	-
331	Blast furnaces and basic steel	14,430	15,500	18,226	18,620	-	-	-	-
332	Iron foundries and ferroalloys	570	600	690	820	-	-	-	-
333, 334	Primary and secondary nonferrous smelting and refining	1,420	1,640	1,880	2,060	4,740	5,490	6,440	7,430
491	Electric power plants	33,600	40,640	49,480	65,840	19,900	25,700	31,900	42,900
Other Misc. Sources									
08	Forestry	250	250	250	250	-	-	-	-
20	Misc. food products	1	1	1	1	-	-	-	-
22	Textile mill products	90	110	130	150	-	-	-	-
24	Lumber and wood products	15	20	20	20	-	-	-	-

TABLE XX-1 (Cont.)
DISCHARGE INVENTORY BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE RESIDUES WHEN TREATED-10^6 KG PER YEAR

SIC	Description	Particulates				Sulfur Oxides			
		1971	1975	1980	1985	1971	1975	1980	1985
Other Misc. Sources (Cont.)									
295	Paving and roofing materials	4,400	6,070	8,490	10,960	-	-	-	-
30	Rubber and misc. plastics	5	7	9	10	-	-	-	-
327	Concrete, gypsum and plaster	3,580	4,300	4,960	5,800	-	-	-	-
336	Nonferrous foundries	30	40	50	60	-	-	-	-
40	Railroad trans.	40	50	60	80	100	120	140	170
42	Trucking and warehousing	270	330	390	460	290	360	420	500
45	Air transport	20	30	30	30	10	12	10	20
5541	Gasoline consump.	350	390	460	540	2,520	2,800	3,410	3,910
4953	Solid waste disposal	280	330	1,240	1,430	—	—	—	—
	Total of other sources	9,370	11,930	16,090	19,690	2,920	3,290	3,980	4,660
	Totals	94,650	111,030	134,130	162,720	31,570	38,970	47,730	61,090

TABLE XX-2
DISCHARGE INVENTORY BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE RESIDUES WHEN TREATED-10^6 KG PER YEAR

SIC	Description	Suspended Solids				BOD5			
		1971	1975	1980	1985	1971	1975	1980	1985
Major Sources									
02	Feedlots[a]	10,080	10,300	10,670	10,790	n.d.	n.d.	n.d.	n.d.
10-12,14	Mining	8×10^5	9×10^5	11×10^5	13×10^5	--	--	--	--
201,202	Meat and dairy products	550	590	640	710	700	750	800	890
203	Canned and preserved fruits and vegetables	390	480	580	670	350	420	520	600
26	Paper and allied products	860	980	1,140	1,240	2,010	2,440	2,930	3,550
28	Chemicals and allied products	510	600	710	850	n.d.	n.d.	n.d.	n.d.
13,291	Petroleum, refining, extraction and trans.	35	35	40	50	100	110	130	140
324-326	Cement and clay	10	15	15	20	n.d.	n.d.	n.d.	n.d.
331	Blast furnaces and basic steel production	11,300	12,090	14,420	15,460				
333,334	Primary and secondary non-ferrous smelting and refining	7,250	9,560	12,620	15,630	n.d.	n.d.	n.d.	n.d.
4952	Sewerage systems	4,610	5,020	5,730	6,560	3,970	4,320	4,930	5,620

TABLE XX-2 (Cont.)

DISCHARGE INVENTORY BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF PRODUCING SOLID WASTE RESIDUES WHEN TREATED-10^6 KG PER YEAR

SIC	Description	Suspended Solids				BOD5			
		1971	1975	1980	1985	1971	1975	1980	1985
Other Miscellaneous Sources									
208	Beverages	10	10	20	20	440	540	640	760
20	Misc. food products	40	40	40	50	60	60	70	80
22	Textile mill products	260	320	370	430	350	420	500	570
31	Leather	100	100	90	90	70	70	70	60
335	Non-ferrous rolling and drawing	20	30	40	40	3	4	5	6
37	Transportation equipment	20	20	20	30	20	20	20	30
	Total of other sources	450	520	580	660	940	1,110	1,300	1,510
	Totals without mining	36,045	40,190	47,145	52,640	8,070	9,150	11,610	12,310
	Total including mining	8×10^5	9 x 105	11×10^5	13×10^5	n.d.	n.d.	n.d.	n.d.

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[a] Suspended solids in runoff and from solid or slotted floors.

TABLE XX-3

TOTAL IMPACT OF AIR AND WATER POLLUTION CONTROLS IN KEY U.S. POLLUTING SECTORS ON SOLID WASTE GENERATION (10^6 KG)

Sector	1971			1975			1980			1985		
	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Wastes
Feedlots	2,000	51	920	2,430	46	1,110	2,830	43	1,220	2,680	43	1,150
Mining	8×10^5	100	8×10^5	9×10^5	100	9×10^5	11×10^5	100	11×10^5	13×10^5	100	13×10^5
Meat and dairy products	420	38	60	490	20	100	570	25	140	660	33	220
Canned and preserved fruits and vegetables	330	15	50	420	12	50	650	11	70	1,000	14	140
Grain mills	1,940	25	500	4,470	31	1,370	6,640	34	2,230	7,880	34	2,700
Paper and allied products	15,060	46	6,910	18,710	50	9,290	22,850	50	11,490	28,120	55	15,340
Chemicals	20,330	48	9,680	22,350	51	11,450	27,200	57	15,630	33,460	57	17,400
Petroleum extraction, refining and transportation	1,500	5	770	2,260	44	590	2,750	45	1,250	3,950	38	1,490
Cement and clay	10,670	35	3,780	12,180	28	3,450	14,150	22	3,120	16,480	16	2,640
Blast furnaces and basic steel prod.	13,530	22	3,020	14,630	23	3,420	17,360	24	4,140	18,630	25	4,600
Iron foundries	280	46	130	360	53	190	690	64	440	820	79	650

TABLE XX-3 (Cont.)

TOTAL IMPACT OF AIR AND WATER POLLUTION CONTROLS IN KEY U.S. POLLUTING SECTORS ON SOLID WASTE GENERATION (10^6 KG)

Sector	1971			1975			1980			1985		
	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Waste	Total Solid Residues[a]	% Solid Waste[b]	Total Solid Wastes
Non-ferrous smelting and refining	8,050	74	5,990	12,880	77	9,950	27,380	84	22,900	32,570	84	27,520
Steam electric power plants	33,500	76	25,600	65,930	79	52,310	119,540	85	101,330	160,090	85	135,550
Sewerage systems	3,140	46	1,540	3,370	55	1,870	3,940	58	2,290	4,110	69	2,830
Hazardous	n.d.		1,030	n.d.		5,980	n.d.		16,260	n.d.		29,770
Misc. Sources												
Misc. foods	50	100	50	50	100	50	60	100	60	70	100	70
Textile mills	360	86	310	430	84	360	500	86	430	580	84	490
Leather products	110	82	90	80	75	60	100	80	80	90	78	70
Solid waste disposal	280	96	270	330	94	310	1,240	95	1,180	1,430	94	1,350
Paving and roofing material	4,400		negl.	6,070		negl.	4,960		240	5,700		320
Other misc.	3,620	0	negl.	4,340		10	8,540		10			
Total misc.	8,820	14	720	11,300	11	790	14,870	26	2,000	18,890	25	2,300
Total (without mining)	115,950	52[c]	60,700	167,440	61[c]	102,320	280,410	65[c]	184,510	315,320	77[f]	244,300

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[a] At 100 percent treatment efficiency.

[b] 100 minus (percent lost in treatment plus percent reused).

[c] Percentage excludes hazardous wastes.

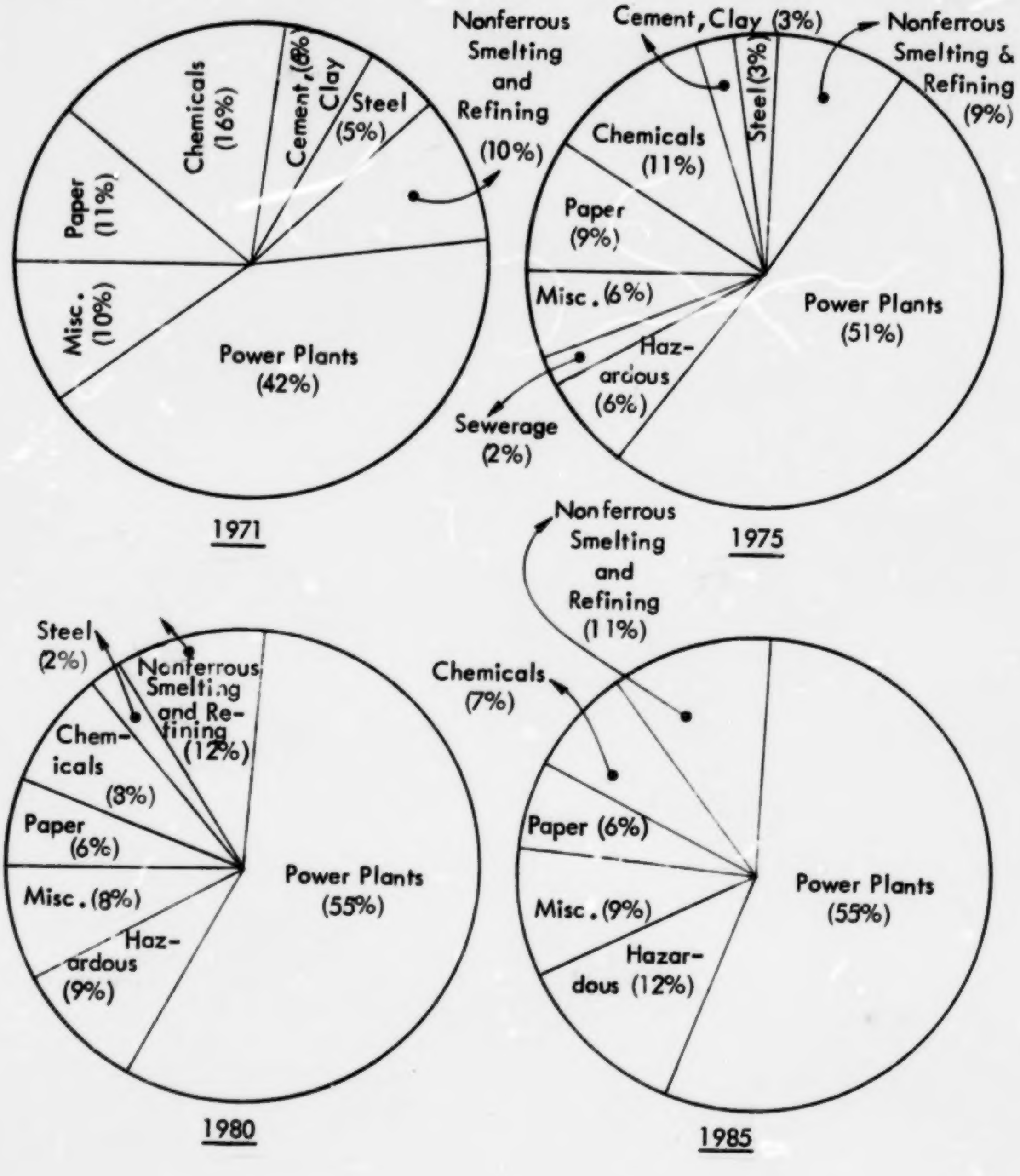

FIGURE XX-2
INDUSTRIAL SECTORS
CONTRIBUTING SOLID WASTES
FROM AIR AND WATER
POLLUTION CONTROL

Aside from power plants the major industrial sectors generating solid wastes from air and water pollution control are nonferrous smelting and refining (SIC 333,334), chemicals and allied products (SIC 28), paper and allied products (SIC 26), cement and clay products (SIC 324, 326), steel (SIC 33), and hazardous-waste producing sectors. With power plants, these sectors contributed 90 percent of all solid wastes from air and water pollution control in 1971 and are expected to increase to 91 percent in the year 1985.

Most of the 29,770 million kg of solid hazardous wastes generated in 1985 will be from uranium mine tailings; these wastes were forecast to increase rapidly because of the increasing role of nuclear power plants as sources of electrical power. Uranium mine tailings, like other mine tailings,are generated near mines, and are not likely to be disposed in urban landfills. The radioactivity of these wastes and their possible leaching into water sources makes such landfilling an area of critical concern.

The degree of reuse for future solid waste residues generated from air and water pollution controls is a very important and also highly uncertain factor affecting the final quantities of solid wastes. Table XX-3 presents the percent solid waste for important contributing sectors; this percentage is one hundred minus the percent lost in treatment and the percent of solid residues reused. Since air and water treatment efficiencies may approach 100 percent in most sectors by 1985, the estimates for that year reflect anticipated reuse. The percent solid waste for the major sectors for 1985 is: power plants, 85 percent; nonferrous smelting and refining, 84 percent; chemicals and allied products, 57 percent; paper and allied products, 55 percent; cement and clay products, 16 percent; and steel mills, 25 percent. No data were available to estimate hazardous solid residue reuse.

The important sectors vary greatly in the usability of their residues from air and water pollution control. Power plant residues are mainly calcium sulfate, calcium sulfite, and waste limestone which have little reuse; nonferrous smelting and refining generates residues which also have minimal value. The usability of paper industry residues is affected by the type of plant; bleached pulp plants have difficulty reusing wastes while unbleached pulp plants generally can recycle many of their wastes. For the most part, wastes from cement and clay production are added back into the products, as are most steel plant waste residues, which are normally sintered.

The estimate of the degree of reuse made in this study resulted from the data in the available literature (which were limited)and from a telephone survey of approximately 50 industrial plants. The estimates are, of course, approximate, since changes in raw material prices, legal constraints, and other factors may significantly affect pollution abatement practices in the future.

Overall, the confidence level for the solid waste projections in Table XX-3 is probably 2, indicating a possible 50 percent variation in the data. The largest source of possible error relates to estimates of the percent of solid wastes reused in the future.

Biodegradability and Destination of Solid Residues.

Tables XX-4 and XX-5 list estimates of the biodegradabilities and ultimate destinations (urban vs. rural) for all residues generated from pollution control for the years 1971 and 1985, respectively. Estimates of biodegradability were based on solid residue composition data presented previously. Estimates of urban or rural disposal destinations were based largely on generation sites of the residues; it was assumed that due to transportation costs, residues would be disposed to land areas nearby their generation, all other things being equal. For 1971, out of a total 60,705 million kg residues, 10,225 million kg (17 percent) were easily biodegradable and the remaining 50,480 million kg (83 percent) were nonbiodegradable; during the same year, 35,510 million kg (59 percent) were destined for rural areas while 25,195 million kg (41 percent) were destined for urban areas. For 1985, out of a total of 244,240 million kg residues, only 23,730 million kg (10 percent) are forecast to be easily biodegradable, and the remaining 220,510 million kg (90 percent) are forecast to be relatively nonbiodegradable; most of the residues, 185,510 million kg (76 percent) are forecast to be disposed to rural sites, with the remaining 58,730 million kg (24 percent) forecast to be disposed to urban sites. Thus, the trend over time appears to be increasingly nonbiodegradable solid waste residues being produced, whose adverse impact on solid waste management will be mediated somewhat by an increasing trend towards disposal in rural sites.

Solid Wastes from Air and Water Pollution Control Compared with Total Solid Waste from all National Sources.

Table XX-6 compares the total solid wastes generated in the United States with the solid wastes from air and water pollution control alone. In 1971, 61 million metric tons of solid wastes were generated by water pollution controls from post-consumer and industrial sources (excluding mining). A total of approximately 214 million metric tons of solid wastes were produced by these U.S. sources in 1971. Wastes from air and water pollution controls, then, contributed approximately 29 percent of all solid wastes produced in 1971. By 1985, total solid wastes from industrial, residential, commercial, and institutional sources were forecast to increase to 370 million metric tons, of which 244 million metric tons are forecast to originate from air and water pollution control, a contribution of 66 percent.

Data are more limited for mineral wastes, but pollution controls are significant here. The 800 million metric tons of wastes from mining tailing ponds for 1971 are over half the 1,540 million metric tons of total mineral wastes for 1969. These 800 million metric tons are forecast to increase to 1,300 million by 1985. Total mining wastes for 1985 are estimated to be 2,895 million metric tons. Most of the wastes listed as air and water pollution control mineral wastes are from tailing ponds, most of which have never been allowed to be released directly to waterways. Very little of the agricultural wastes of 2,070 million metric tons for that year is derived from air and water pollution controls. Solid waste residues from pollution control are expected to form a significantly greater percentage of total post-consumer and industrial solid waste, increasing from 29 percent in 1971 to an estimated 66 percent in 1985.

TABLE XX-4

BIODEGRADABILITY AND DESTINATION OF SOLID WASTE RESIDUES FROM POLLUTION CONTROL (10^6 KG)--1971

Sector	Destined for Rural Disposal Sites		Destined for Urban Disposal Sites	
	Easily Biodegradable	Non-Biodegradable	Easily Biodegradable	Non-Biodegradable
Major Sectors				
Feedlots	1,920			
Mining		(8×10^5)[a]		
Meat and dairy products			65	
Canned and preserved fruits and vegetables			50	
Grain mills	500			
Paper and allied products	6,910			
Chemicals				9,680
Petroleum extraction, refining and trans.		550		220
Cement and clay				3,780
Blast furnaces and basic steel				3,020
Iron foundries				130
Primary and secondary non-ferrous metals				5,990
Steam electric power plants		25,600		
Sewerage systems			1,540	
Hazardous		1,030		
Minor Sectors				
Forestry		negl.		
Misc. food			50	
Textile mills			150	160

TABLE XX-4 (Cont.)

BIODEGRADABILITY AND DESTINATION OF SOLID WASTE RESIDUES FROM POLLUTION CONTROL (10^6 KG)--1971

Sector	Destined for Rural Disposal Sites		Destined for Urban Disposal Sites	
	Easily Biodegradable	Non-Biodegradable	Easily Biodegradable	Non-Biodegradable
Minor Sectors (Cont.)				
Leather, lumber, and wood			40	50
Paving and roofing material				
Rubber and misc. plastics				
Concrete gypsum and plaster				
Non-ferrous foundries				
Railroad transportation				
Trucking and warehousing				
Air transportation				
Automobiles				
Solid waste disposal (incineration control)			270	
Totals	8,330	27,180	1,895	23,300
Total rural	35,510			
Total urban	25,195			
Total biodegradable	10,225			
Total not easily biodegradable	50,480			
Grand total	60,705			

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[a] Not included in totals.

TABLE XX-5

BIODEGRADABILITY AND DESTINATION OF SOLID WASTE RESIDUES FROM POLLUTION CONTROL (10^6 KG)--1985

Sector	Destined for Rural Disposal Sites		Destined for Urban Disposal Sites	
	Easily Biodegradable	Non-Biodegradable	Easily Biodegradable	Non-Biodegradable
Major Sectors				
Feedlots	1,150			
Mining		(13×10^5)[a]		
Meat and dairy products			220	
Canned and preserved fruits and vegetables			140	
Grain mills	2,700			
Paper and allied products	15,340			
Chemicals				17,400
Petroleum extraction, refining and trans.	1,000			490
Cement and clay				2,640
Blast furnaces and basic steel				4,600
Iron foundries				650
Primary and secondary non-ferrous metals				27,520
Steam electric power plants		135,550		
Sewerage systems			2,830	
Hazardous		29,770		
Minor Sectors				
Forestry				
Misc. food			70	
Textile mills			240	250

TABLE XX- 5 (Cont.)

BIODEGRADABILITY AND DESTINATION OF SOLID WASTE RESIDUES FROM POLLUTION CONTROL (10^6 KG)--1985

Sector	Destined for Rural Disposal Sites		Destined for Urban Disposal Sites	
	Easily Biodegradable	Non-Biodegradable	Easily Biodegradable	Non-Biodegradable
Minor Sectors (Cont.)				
Leather products, lumber and wood			40	30
Paving and roofing materials				320
Rubber and misc. plastics				
Concrete gypsum and plaster				
Non-ferrous foundries				
Railroad transportation				
Trucking and warehousing				
Air transportation				
Automobiles				
Solid waste disposal (incineration control)				1,350
Totals	20,190	165,320	3,540	55,190
Total rural	185,510			
Total urban	58,730			
Total biodegradable	23,730			
Total not easily biodegradable	220,510			
Grand total	244,240			

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[a] Not included in totals.

TABLE XX-6
SOLID WASTE RESIDUES FROM AIR AND WATER POLLUTION CONTROL VS. TOTAL SOLID WASTES

Source	Millions of Metric Tons 1971 From Pollution Control	Total	%	1985 From Pollution Control	Total	%
Post-consumer[436]	--	114	--	--	182[a]	--
Industrial, except mineral	--	100[b]	--	--	188[c]	--
Subtotal: post-consumer & industrial	61	214	29	244	370	66
Mineral	800	1,540[b]	52	1,300	2,895[c]	45
Agricultural	negl.	2,070[b]	0	negl.	3,891[c]	0

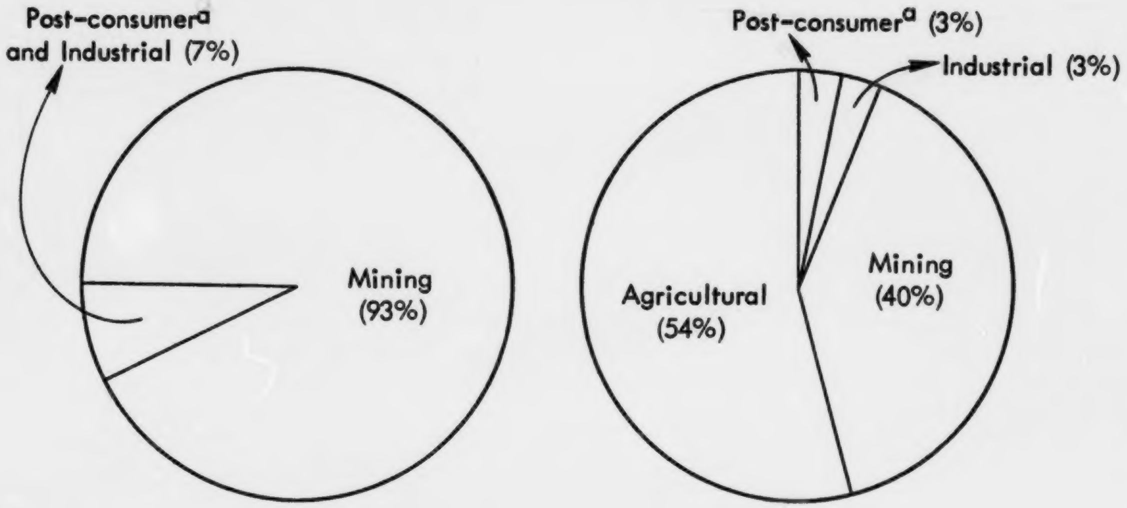
[a] Assumes 60 percent increase between 1971 and 1985.

[b] 1969 data from Reference 298.

[c] Assumes 88 percent increase between 1971 and 1985.

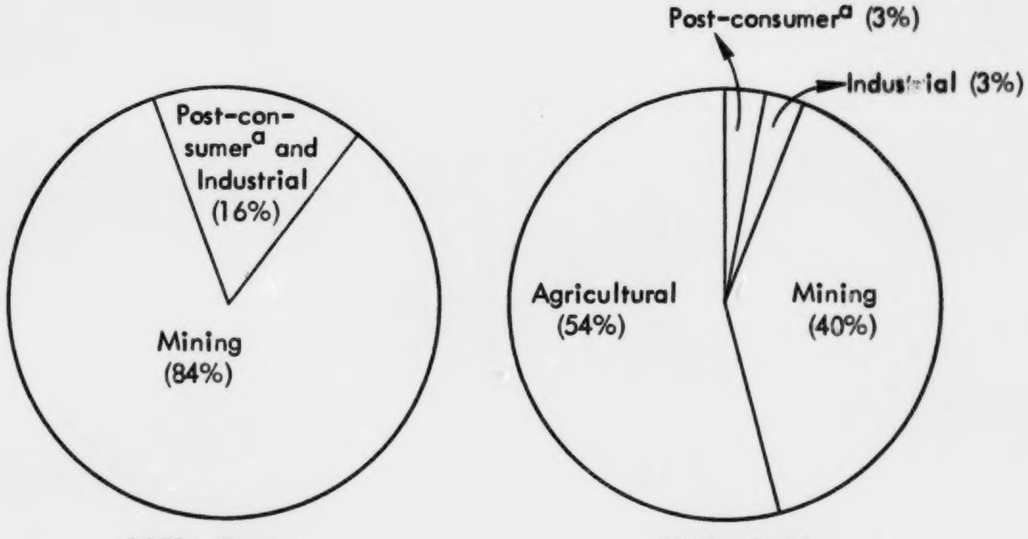
The solid waste residues from air and water pollution control versus the total solid wastes in the United States is presented in Figure XX-3. Solid wastes from various societal sources (post-consumer, industrial, mineral and agricultural) are listed as percentage contributions of total U.S. residues generated and total residues from pollution control alone for the years 1971 and 1985. For 1971, total solid waste generation was primarily from agriculture (54 percent) and mining (40 percent); post-consumer and industrial sources each contributed but three percent. The corresponding 1971 figures for residues from air and water pollution control are: mining - 93 percent; and post-consumer/industrial - seven percent. Total 1985 solid waste residue generation by contributing source is forecast to maintain the same percentages as in 1971. However, residues from pollution control in 1985 will likely show a percentage decrease from 1971 for mining to 84 percent, with post-consumer/industrial sources registering a projected sixteen percent.

Of prime significance, then, is the forecast change between 1971 and 1985 in the percentages of solid waste residues generated from air and water pollution control by various societal sectors. Post-consumer and industrial sources (subtotalled) will increase rather substantially as a percentage of the total solid wastes from pollution control; this will be a result of the more stringent controls to be effected in the coming years on the residues and waste-producing activities of these sectors. Mining residues as a relative percentage of solid wastes generated from pollution control will accordingly decrease (although the absolute quantity of residues will grow - see Table XX-6). Agricultural solid waste residues, controlled negligibly in 1971, will similarly receive negligible control through 1985.



1971 - From Pollution Control

1971 - Total



1985 - From Pollution Control

1985 - Total

FIGURE XX-3
SOLID WASTE RESIDUES FROM
AIR AND WATER POLLUTION CONTROL
VS. TOTAL U.S. SOLID WASTE GENERATION

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[a] Normal solid waste.

Solid Wastes from Air and Water Pollution Control Categorized by Pollutant Treatment Source.

Table XX-7 and Figure XX-3 present solid wastes from air and water pollution for 1971 and 1985 identified by the pollutant from which they were derived. Particulates, sulfur oxides, and miscellaneous air pollutants are identified, while all water pollutants are grouped together; since suspended solids and biological oxygen demand overlap, it was impossible to separate the source of the residues from water pollution control. The pollutant contributions in Table XX-7 are broken down by major contributing sectors. In 1971, 62 percent of all solid wastes from air and water pollution control were generated by particulate control, while 37 percent were generated by the control of all water pollutants. Solids removed from air pollution scrubber effluent water were included with the original air pollutant controlled. By 1985, sulfur oxide control will likely be a more significant contributor(forecast to be 39 percent) with particulates reduced to about 40 percent and water pollutants contributing 21 percent. The main source of this large projected increase is increased sulfur oxides control in electric power plants by limestone scrubbing.

Tables XX-9 and XX-10 list total forecast solid wastes from air and water pollution control for 1971 and 1985, respectively, identified by the air and water treatments which generated the residues. The percentage contribution by the various treatments is also shown in Figure XX-4. Table XX-8 explains the treatment categories used in Tables XX-9 and XX-10. The air pollution treatments are categorized into mechanical, electrostatic, water scrubbing and wet chemical treatment. Mechanical air treatment includes those treatments which use dry physical removal mechanisms such as cyclones and baghouses, while electrostatic treatment includes all types of electrostatic precipitators. Water scrubbers use pure water to scrub solids from flue gases, while wet chemical treatments include methods which use chemicals in the scrubber water in order to capture gaseous pollutants. Limestone scrubbing, the most significant wet chemical method, reacts limestone with sulfur oxides in order to form calcium sulfate and sulfite which may be precipitated from water. Water pollution treatments are categorized into primary, chemical secondary, biological secondary, and advanced. Primary treatments include physical systems such as screening, flotation, and sedimentation. Chemical secondary treatments react chemicals with the pollutants in order to cause them to precipitate from solution; biological treatments utilize bacteria in order to decompose organics in water. Advanced treatments include methods which are efficient in the removal of dissolved solids such as ion exchange, reverse osmosis, etc.

In 1971, 49 percent of all solid residues were produced by water scrubbing systems, 20 percent by primary water treatment, and 10 percent by chemical secondary water treatments. By 1985, chemical scrubbing is forecast to increase to 40 percent of all solid wastes from air and water pollution control, reducing water scrubbing and primary water treatment to 32 and 12 percent, respectively. The main factor underlying this increase in the contribution of chemical scrubbing was the projected application of limestone scrubbing of electric power plant sulfur oxide emissions.

TABLE XX-7

AIR AND WATER POLLUTANTS WHOSE CONTROL GENERATES SOLID WASTE RESIDUES

Industry	1971 10^6 kg Residues (dry wt.)				1985 10^6 kg Residues (dry wt.)			
	Particulates	Sulfur Oxides	Other Air	Water	Particulates	Sulfur Oxides	Other Air	Water
Feedlots	0	0	0	920	0	0	0	1,150
Mining	460	0	0	8×10^5	1,410	0	0	13×10^5
Meat and dairy	0	0	0	60	0	0	0	220
Fruits and vegetables	0	0	0	50	0	0	0	140
Grain mills	500	0	0	0	2,700	0	0	0
Paper and allied prod.	2,440	0	0	4,470	5,800	0	0	9,540
Chemicals and allied	3,140	470	20	6,050	5,860	1,300	90	10,150
Petroleum refining	200	0	0	570	420	0	0	1,070
Cement and clay	3,690	0	0	90	2,550	0	0	90
Blast furnaces and steel	300	0	170	2,550	320	0	310	3,970
Iron foundries	130	0	0	0	650	0	0	0
Non-ferrous metals	800	0	0	5,190	2,350	9,070	0	16,100
Power plants	25,600	0	0	0	62,530	73,000	0	20
Sewerage systems	0	0	0	1,540	0	0	0	2,830

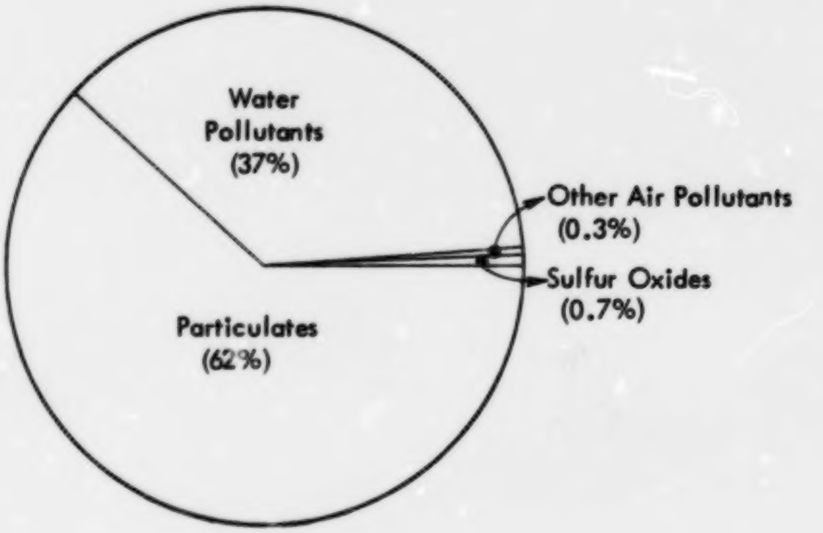
TABLE XX-7 (Cont.)

AIR AND WATER POLLUTANTS WHOSE CONTROL GENERATES SOLID WASTE RESIDUES

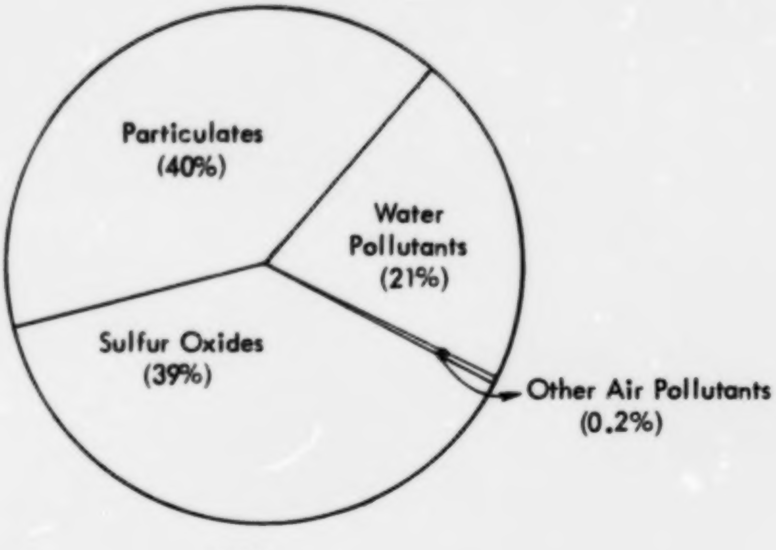
Industry	1971 10^6 kg Residues (dry wt.)				1985 10^6 kg Residues (dry wt.)			
	Particulates	Sulfur Oxides	Other Air	Water	Particulates	Sulfur Oxides	Other Air	Water
Other sources	370	0	0	350	1,820	0	0	480
Total (excluding mining)	37,170	470	190	21,840	85,000	83,370	400	45,760
Hazardous waste streams	1,030 x 10^6 kg in 1971				29,770 x 10^6 kg in 1985			
Percent of total[a, b]	62	0.7	0.3	37	40	39	0.2	21

[a] 1971 total, excluding mining and hazardous wastes, is 59,670 x 10^6 kg.

[b] 1985 total, excluding mining and hazardous wastes, is 214,530 x 10^6kg.



1971



1985

FIGURE XX-4
AIR AND WATER POLLUTANT CONTRIBUTIONS
TO SOLID WASTE RESIDUES

TABLE XX-8

CATEGORICAL BREAKDOWN OF TREATMENT PROCESSES

WATER TREATMENTS

Primary	Secondary		
	Chemical	Biological	Advanced
Spill control	Neutralization	Anaerobic	Ion exchange
Separation	Demineralization	Trickling filter	Activated carbon
Evaporation	Demineralization, plus evaporation	Aerobic lagoon	Reverse osmosis
Deep-well disposal	DAF[a] and coagulation	Oxidation ditches	Sand filtration
In-plant controls	Sedimentation, plus stablization	Activated sludge	Soil filtration
Storage	Coagulation, plus sedimentation	Coagulation, plus lagoons	Diatomaceous filtration
Screening	Evaporation-crystallization	Soil filtration	Mixed media filtration
Process modification	Cryolite precipitation		
Clarifier	Limestone precipitation		
Skimming	Catalytic breakdown		
DAF[a]	Carbonation, plus sedimentation		
	Activated carbon		

AIR TREATMENTS

Dry		Wet	
Mechanical	Electrostatic	Water	Chemical
Cyclone	Electrostatic precipitators	Wet scrubbers	Pack tower
Fabric filter			Mist eliminator
Baghouse			Limestone scrubber
Lint filters			Sulfuric acid scrubber
Nuclear controls			Catalytic reactor

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[a] Dissolved air flotation.

TABLE XX-9

POLLUTION TREATMENT PROCESSES CONTRIBUTING TO SOLID WASTE GENERATION[a]

1971

Industry	Air Treatment (10^6 kg)				Water Treatment (10^6 kg)				Industry Total
	Mechanical	Electrostatic	Wet		Primary	Secondary		Advanced	
			Water	Chemical		Chemical	Biological		
Feedlots	0	0	0	0	250	0	670	0	1,020
Mining	0	0	0	0	8×10^5	1,260	0	0	8×10^5
Meat and dairy	0	0	0	0	20	20	20	0	60
Fruits and vegetables	0	0	0	0	40	10	1	2	50
Grain mills	500	0	0	0	0	0	0	0	500
Paper and allied prod.	0	1,450	990[b]	0	320	370	1,920	1,860	6,910
Chemicals and allied	890	730	1,540	470	4,480	1,570	0	0	9,680
Petroleum refining	0	200	0	0	550	0	0	20	770
Cement and clay	1,120	460	2,100	0	0	80	20	0	3,780
Blast furnaces and steel	30	80	200	170	0	2,540	0	0	3,020
Iron foundries	80	0	50	0	0	0	0	0	130

TABLE XX-9 (Cont.)

POLLUTION TREATMENT PROCESSES CONTRIBUTING TO SOLID WASTE GENERATION[a]

1971

Industry	Air Treatment (10^6 kg)				Water Treatment (10^6 kg)				Industry Total
	Mechanical	Electrostatic	Wet		Primary	Secondary		Advanced	
			Water	Chemical		Chemical	Biological		
Non-ferrous metals	800	0	0	0	5,190	100	0	0	5,990
Power plant	0	0	25,600	0	0	0	0	0	25,600
Sewerage systems	0	0	0	0	370	580	590	0	1,540
Other sources	110	200	60	0	90	50	210	0	720
Total (excluding mining)	3,500	3,080	29,400	1,780	12,470	5,920	2,850	1,880	59,670
Percent of total	5	5	49	3	20	10	5	3	100

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[a] Does not include hazardous wastes.

[b] Unless otherwise shown, effluent from wet air pollution controls is assumed to be handled by sedimentation.

TABLE XX-10
POLLUTION TREATMENT PROCESSES CONTRIBUTING TO SOLID WASTE GENERATION [a]
1985

Industry	Air Treatment				Water Treatment				Industry Total
	Mechanical	Electrostatic	Wet		Primary	Secondary		Advanced	
			Water	Chemical		Chemical	Biological		
Feedlots	0	0	0	0	310	0	840	0	1,150
Mining	0	0	0	0	1.3×10^6	(32,690)	0	0	1.3×10^6
Meat and dairy	0	0	0	0	10	70	20	120	220
Fruits and vegetables	0	0	0	0	90	20	0	30	140
Grain mills	2,700	0	0	0	0	0	0	0	2,700
Paper and allied prod.	0	4,900	900[b]	0	310	5,120	1,710	2,400	15,340
Chemicals and allied prod.	1,760	1,010	3,180	1,300	7,850	2,300	0	0	17,400
Petroleum refining	0	420	0	0	1,000	0	0	70	1,490
Cement and clay	1,770	570	210	0	0	90	0	0	2,040
Blast fumaces and steel	90	400	240	310	0	3,560	0	0	4,600
Iron foundries	350	0	300	0	0	0	0	0	650
Non-ferrous metals	1,130	0	150	10,590	15,610	40	0	0	27,520

TABLE XX-10 (Cont.)
POLLUTION TREATMENT PROCESSES CONTRIBUTING TO SOLID WASTE GENERATION[a]
1985

	Air Treatment				Water Treatment				Industry Total
Industry	Mechanical	Electrostatic	Wet		Primary	Secondary		Advanced	
			Water	Chemical		Chemical	Biological		
Power plant	3	0	62,530	73,000	0	0	0	20	135,550
Sewerage systems	0	0	0	0	510	11,600	1,160	0	2,830
Other sources	470	1,080	270	0	70	70	340	0	2,300
Total (excluding mining)	8,270	8,380	67,780	85,200	25,760	12,430	4,070	2,640	214,530
Percent total	3	4	32	40	12	6	2	1	100

[a] Does not include hazardous wastes.

[b] Unless otherwise shown, effluent from wet air pollution controls is assumed to be handled by sedimentation.

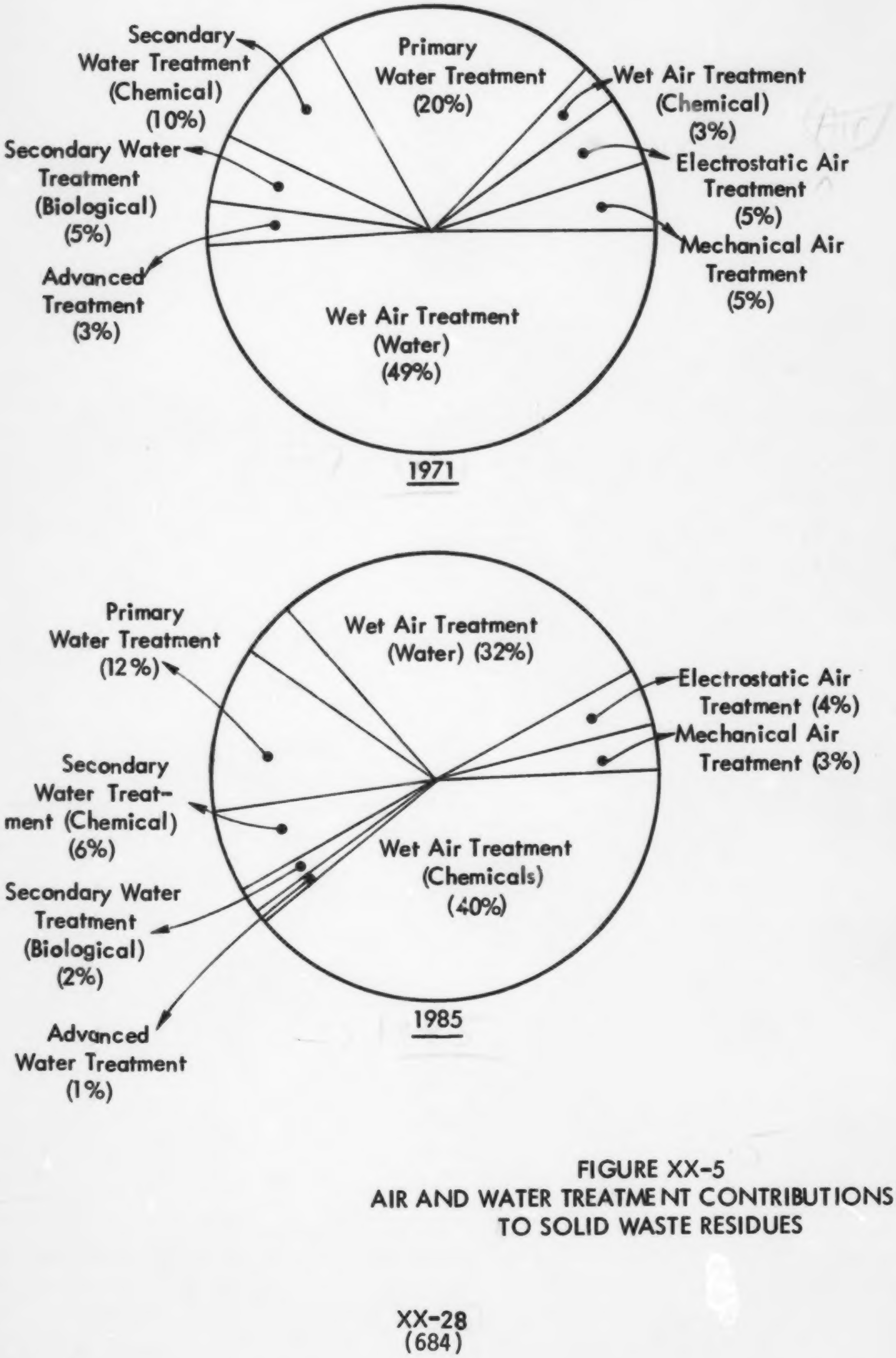

FIGURE XX-5
AIR AND WATER TREATMENT CONTRIBUTIONS
TO SOLID WASTE RESIDUES

Summary of Impacts of Key Industrial Sectors.

A brief summary of the major individual contributors (by SIC category) of solid waste residues from air and water pollution control is presented below. More detailed analysis can be found in the preceding Sections of this report dealing with particulate residues.

Feedlots, SIC 02 (Section IV). Pollutants generated by housing animals in feedlots are mainly dry solids, BOD, ash, and nitrogenous wastes; these pollutants are either directly discharged into the water medium or removed via mechanical means. The main sources of water pollutants in this sector are: milk rooms(for dairy cattle) and housing (barns, yards, etc., for all other animals), and storm drainage runoff. Total untreated solids generated from dirt lots were forecast to increase from 20,000 million kg in 1971 to 25,466 million kg in 1985; total untreated solids generated from solid and slotted floors were forecast to increase from 28,665 million kg to 30,264 million kg during the same period.

Common waste-removal methods are mainly mechanical (e.g., scraping) and water flushing. Mechanical removal creates residues which are usually reclaimed; flushed wastes, along with drainage runoff, must undergo effluent treatment. These treatments, which all produce some solid waste residues, are mainly lagooning, oxidation ditches, activated sludge, and evaporation. Of the various alternative disposal methods, land composting and other utilizations provide complete reuse, feed recycling involves 80 percent reuse, dehydration 43 percent reuse, oxidation ditch refeed 25 percent, and incineration none.

Total solid residues from pollution control in feedlots were forecast to decrease from 6,460 million to 5,790 million kilograms between 1971 and 1985. Of these, the majority (5,540 million kg in 1971) is derived from solids removed from animal manure with dry processes. Between 1971 and 1985, solid residues from water treatment processes were forecast to increase to 1,160 million kg from 920 million kg. For the same period, solid waste residues removed via dry processes were forecast to decrease from 5,540 to 4,560 million kg. This forecast reduction is a consequence of the forecasted increase in solid waste reuse, and a corresponding decrease in landfill disposal,between 1971 and 1985. Raw waste residues from feedlots were estimated to be composed of about 84 percent water. Of the dry residue, approximately 70 percent is biodegradable, 30 percent ash, 17 percent potassium, three percent phosphorus, and one percent magnesium.

Mining, SIC 10-12, 14 (Section V). Particulate emissions in mining and milling operations are very large. Total emissions before treatment were forecast to increase from 8,000 million kg in 1971 to 13,100 million kg in 1985. Huge amounts of suspended solids are discharged before treatment. Tailing ponds have been in common use long enough so that partial suspended solids control is an accepted practice in the industry. Suspended solids before treatment were forecast to increase from 8×10^{11} kg in 1971 to 13×10^{11} kg in 1985. Both process water and drainage water contribute to this pollutant load.

Cyclones and baghouses are the most common air pollution control devices, although wet scrubbers are utilized in some milling operations. Sedimentation in tailing ponds removes the overwhelming portion of suspended solids discharged by mines, and neutralization followed by sedimentation is used to treat acid mine drainage. Passive controls entail the sealing of "dead"mines to prevent the discharge of drainage waters. The degree of reuse of solid residues from air and water pollution control is a function of mine type, product quality, etc. Metal mines typically do not recycle residues, while coal cleaning produces both usable and solid waste residues. Normally, dust collected from non-metal mining can be reused.

Total solid residues from air and water pollution control in mines and ore milling operations were forecast to increase from 8×10^{11} kg in 1971 to 13×10^{11} kg in 1985, mostly from tailing ponds. This tends to obscure the very significant quantities of solid waste residues from air pollution control and drainage from dead mines; waste residues from air pollution control were forecast to increase from 510 million kg in 1971 to 1,500 million kg in 1985. The impact of total solid wastes is not as important as it seems from the quantities involved, since the mines from which they originally came are near at hand and are natural disposal sites. The cost of reclaiming strip mined land is significant, however, and so the solid wastes have an economic impact even though they do not directly create a residue which cannot be handled locally. The heavy metal content of solid wastes from air and water pollution controls in mines causes these residues to have toxicity problems, particularly when water leaches through disposal sites.

Meat and Dairy Products, SIC 201, 202 (Section VI). The majority of pollutants generated by this industry are derived from slaughtering and by-product handling and are released to water. Air pollutants from the industry are relatively insignificant. Untreated BOD_5 discharges were forecast to increase from 700 to 890 million kg between 1971 and 1985; total suspended solids discharges during the same period were forecast to increase from 590 to 710 million kg. Meat products account for the majority of these untreated BOD_5 and SS discharges. This sector, in addition, was forecast to generate significant amounts of untreated dissolved pollutants (e.g., phosphorus, chlorides); dissolved pollutant generation is forecast to increase from 257 to 334 million kg between 1971 and 1985.

Primary in-plant controls (e.g., screening, settling) are common in the meat products industry, and produce significant quantities of solid waste residues. Common wastewater treatment for meat and dairy product effluents are biological treatments, spray irrigation, ultrafiltration, reverse osmosis, dissolved air flotation, coagulation, lagooning, aeration, trickling filtration, and ion exchange. Ion exchange is used generally for dissolved pollutants only, and the remaining treatments are used for suspended solids and other flotables. From the latter advanced wastewater treatments, solid wastes are generated mostly from aerobic lagooning followed by trickling filtration, dissolved air flotation followed by inorganic coagulation, and ion exchange. The main instances of reuse in these industries are use of integument as food supplements for animals, and similar by-product reclamation of the grease produced from dissolved air flotation.

Total solid residues from water pollution control in these sectors were forecast to increase from 60 to 220 million kilograms, between 1971 and 1985. The vast majority of the solid waste residues produced will likely be from meat products, which are also forecast to be responsible for the majority of untreated discharges. The small 1971 contribution of the dairy products sector, 16 million kg, was forecast to decline to 6 million kg by 1985.

Canned and Preserved Fruits and Vegetables, SIC 203 (Section VII). This sector generates few air pollutants but a substantial quantity of water pollutants. Total BOD_5 discharges before treatment were forecast to increase from 350 million kilograms in 1971 to 600 million kilograms in 1985; total suspended solids discharges were forecast to show a similar increase from 390 to 670 million kg during the same period. Most plants currently employ primary treatment processes such as screening, sedimentation, and flotation. Secondary controls will be required by 1977 and further improvements by 1983.

Although large amounts of solid waste are generated in this sector (both during processing and as a result of pollution control), their reuse potential is high (mostly for animal feed). Approximately 80 percent of the residues generated from pollution control were forecast to be reused. For 1971 and 1985, final solid waste residues for land disposal were forecast to be only 50 million kg and 140 million kg, respectively. The waste residues are mainly organic and may be used as a soil conditioner or for spray irrigation. Because of their organic content, solids disposal in landfills presents no major problems.

Grain Mills, SIC 204 (Section VIII). Grain mills generate air pollutants (particulates) almost exclusively; these particulate emissions are largely controlled by dry methods. The cyclone is currently the predominate treatment method; fabric filters are more efficient and are likely to be the major treatment method by 1985. Total uncontrolled particulate discharges were forecast to increase from 4.8 billion kg in 1971 to 7.8 billion kg by 1985.

Treatment generated an estimated 500 million kg of solid waste residues in 1971, a weight forecast to increase to 2,700 million kg in 1985. These figures assume a fairly high degree of reuse. As more fines are captured with more stringent emission control equipment, the degree of reuse will decline slightly.

Papers and Allied Products, SIC 26 (Section IX). The recycling process is the major source of water pollutants. Significant quantities of air pollutants, sulfur oxides, particulates, and hydrogen sulfide are also emitted. Most air pollution control is currently accomplished with wet scrubbers, although electrostatic precipitators may be used more in the future. Primary and secondary treatments are applied to the effluent stream to control suspended solids and BOD_5, while carbon absorption and lime coagulation are used to control the discharge of color (lignins).

The total solid waste residues from air and water pollution control were forecast to increase over the period 1971 to 1985 from 6,910 to 15,350 million kg. Although currently (1974) most wastes are incinerated or landfilled, the use of recovered fibers in the building materials industry, of dried activated sludge as a fuel, and of processed activated sludge as a commercial soil conditioner holds promise for future recycling.

Chemicals and Allied Products, SIC 28 (Section X). This sector generated substantial quantities of both air and water pollutants. Particulates are discharged from the production of carbon black, plastics, nitrate and phosphate fertilizer, and phosphoric acid. Sulfur oxides and hydrogen sulfides are discharged from sulfuric acid and carbon black, respectively. The untreated discharges of particulates and sulfur oxides were forecast to increase from 6,370 million kg in 1971 to 10,390 million kg in 1985. Untreated water pollution discharges in the form of suspended and dissolved solids generated by the manufacture of inorganic chemicals amounted to 14.9 billion kg in 1971 and were projected to increase to 20.9 billion kg in 1985. Untreated sludge from the production of plastics and synthetics and untreated BOD_5 load from the manufacture of organic chemicals were forecast to increase from 93 million kg and 3,647 million kg in 1971, respectively, to 324 million kg and 8,336 million kg in 1985.

Air pollution treatments applied in the chemical manufacturing industry are primarily bag filters, cyclones, electrostatic precipitators, wet and dry scrubbers, and incinerators. The reuse of the residues generated by pollution treatment is fairly common in the industry. Water pollutants are typically subjected to settling and clarification to remove settleable solids in the effluent prior to being neutralized, evaporated, or lagooned.

Total solid waste residues resulting from air and water pollution controls in this sector were projected to reach 17,400 million kg in 1985, a considerable increase of 80 percent over the 1971 level of 9,680 million kg. Residues derived from air pollution control are mainly attributable to fertilizer, carbon black, and sulfuric acid manufacture; those derived from water pollution control are mainly attributable to inorganic chemicals and plastics, and synthetics manufacture. Required advance water pollution treatments alone will create 820 million kg of solid waste in 1985, as compared with a zero level of solid waste residues in 1971.

Petroleum Extraction, Refining and Transportation, SIC 13, 291 (Section XI). Oil extraction and transportation primarily generate water pollutants; refining generates both air and water pollutants. Total uncontrolled particulate emissions from this industry were forecast to increase from 300 million kg in 1971 to 430 million kg in 1985. Sulfur oxides were forecast to increase from 3,480 million kg in 1971 to 4,990 million kg in 1985. Crude oil spills were forecast to remain constant at 65.5 million kg of oil through 1985, as improved technology offsets increased oil drilling and transportation. Brine salts were forecast to increase from 550 million kg in 1971 to 1,130 million kg in 1985, although this is highly dependent on the percentage reinjected into the ground. Refinery operations produce large quantities of BOD_5, oil and grease, phenols, ammonia, suspended solids, and miscellaneous other pollutants. BOD_5 discharges were forecast to increase from 100 million kg in 1971 to 140 million kg in 1985, and suspended solids from 35 to 50 million kg over the same period.

Refinery particulate emissions are commonly controlled by electrostatic precipitators, although a few baghouses may be used in the future. Sulfur recovery plants are the common method of sulfur oxide control in refineries. These plants produce a saleable by-product and generate no solid waste. The treatment of brines to extract valuable minerals leaves 85 to 90 percent of the original dry weight of brine treated as solid waste requiring disposal. The cleanup of oil spills is done by a combination of surface skimming and the use of various sorbents. The skimmed product may many times be processed to yield refinery crude feedstocks. Sometimes the sorbents are squeezed to yield crude oil and regenerate the sorbents for reuse.

Total solid waste residues from air and water pollution control in the petroleum industry were forecast to increase from 770 million kg in 1971 to 1,490 million kg in 1985. A large proportion of these wastes were forecast to be generated by brine disposal, which is performed near the extraction site and can only be roughly estimated. The mixtures of oil and sorbents from oil spill cleanup are normally sent to landfills when the sorbents are not reprocessed.

The main pollutant generated during cement and clay manufacture is particulates. Total untreated discharges from the sector were forecast to almost double from 1971 (8,200 million kg) to 1985 (15,813 million kg). Some water pollution is created through intermedial transfer to water during control. The large percentage of kiln dust and wastewater reused in both cement and clay manufacture lessens on solid waste residue generation from pollution treatment processes.

The total solid waste residues from control were forecast to decrease from 3,780 million kg in 1971 to 2,640 million kg in 1985. This decline was attributed to increased recycling forecast for the future. Most pollutants which are captured in solid form may be added back into the batch due to the nature of cement and clay.

Blast Furnaces and Steel Mills, SIC 331 (Section XIII). This industry is a significant contributor to both uncontrolled air pollution (particulates, hydrocarbons, and carbon monoxide) and uncontrolled water pollution (suspended solids). Significant quantities of particulates are generated from steel furnaces (especially basic oxygen), and during coking, reduction, scarfing, and sintering. Large quantities of suspended solids are discharged to water during blast furnace reduction and sintering, and from steel furnaces and rolling mills. Iron sulfate and sulfuric acid are generated in significant quantities during pickling. Total uncontrolled particulate discharges from SIC 331 were forecast to increase to 18.6 billion kg in 1985 from 14.4 billion kg in 1971; uncontrolled SS discharges were forecast to increase from 11.3 to 15.5 billion kg during the same period.

The main treatment methods that were forecast to be used to control particulate and other air pollutant discharges in blast furnaces are fabric and other filters and precipitators. Control of particulate emissions from steel furnaces can be economically accomplished through wet scrubbers as well as fabric filters and precipitators. Medium energy wet scrubbers are sufficient for particulate control during sintering. Suspended solids generated from blast furnaces and rolling mills and during sintering can be controlled through a combination of recirculation, coagulation, and sedimentation. Iron sulfate and sulfuric acid in pickle liquor can be removed through lime neutralization followed by sedimentation, evaporation followed by crystallization, or dialysis. Potential reuse of pollutants in blast furnaces and steel mills is high.

Total solid residues generated from air and water pollution control in blast furnaces and basic steel mills were forecast to increase from 3,020 million kg in 1971 to 4,600 million kg in 1985. Most of these residues will be derived from water pollution control; this includes particulates transferred to water from air pollution controls (scrubbers and precipitators). The main sources of these residues will be particulates generated from blast furnaces and basic oxygen steel furnaces, and suspended solids generated from hot rolling mills. The residues generated from steel furnace pollution control will be fairly dry, inert, and non-biodegradable, and will contain no hazardous substances. Solid residues generated through lime neutralization during pickling will tend to be more corrosive and toxic, but these are a relatively minor contribution to total residues generated.

Iron Foundries and Ferroalloy Production, SIC 3312 and 332 (Section XIV). Particulates are the only significant pollutant generated in this industry. Most particulate emissions from iron foundries are from cupola furnaces. Total uncontrolled particulate discharges were forecast to increase from 570 million kg in 1971 to 820 million kg in 1985.

Baghouses and wet scrubbers are the most common air pollution control devices used in this sector. Although data are scarce concerning the reuse of the residues created by pollution control, indications are that a not insignificant portion of the residues generated is reused in the foundries themselves or is sold for incorporation in cement production as heavy metal constituents in fertilizers. The total solid waste residues generated by air pollution control were forecast to increase from 130 million metric tons in 1971 to 650 million kg in 1985.

Primary and Secondary Nonferrous Smelting and Refining, SIC 333, 334 (Section XV). Nonferrous smelting and refining is a significant contributor to National discharges of both air and water pollutants. Total particulate discharges before treatment are forecast to increase from 1,420 million kg in 1971 to 2,060 million kg in 1985; over 95 percent of these emissions stem from primary smelting and refining. Sulfur oxide emissions before treatment were forecast to increase from 4,740 million kg in 1971 to 7,430 million kg in 1985. These emissions also stem primarily from primary smelting and refining with secondary nonferrous smelting and refining playing only a relatively minor role. Suspended solids are also significant for this sector, although reliable data exist only for bauxite refining, whose discharges were forecast to increase from 7,250 million kg in 1971 to 15,630 million kg in 1985.

Both mechanical and wet scrubbing methods are used to control particulate emissions while fabric filters are becoming increasingly popular. Some plants currently control sulfur oxide emissions by the use of sulfuric acid recovery plants. In the future, limestone scrubbers may be used on the recovery plant tail gases in order to achieve the required level of control; this would increase the solid waste residues generated. Ponding and limestone precipitation are the current methods of controlling water pollutants. These methods create residues with little or no potential for reuse with the exception of cryolite precipitation from which 30 percent of the residues may be reused.

The total solid waste residues from air and water pollution control in this sector were forecast to increase from 5,990 million kg in 1971 to 27,520 million kg in 1985. Limestone scrubbing of sulfur oxide emissions contributes the majority of solid wastes from air pollution control while settled mud from bauxite refining contributes most of the water pollution control solid waste residues. Metal oxides are prevalent in settled mud from bauxite refining. A landfill receiving solid waste residues from non-ferrous smelting and refining could be expected to have a relatively high metals content in its leachate.

Electric Power Plants, SIC 491 (Section XVI). Fossil fuel and nuclear fission power plants are significant contributors to the National pollution load. The former contributions are significant in terms of residue weight, while the latter are significant in terms of radioactive hazards. Fossil fuel plants release to the air significant quantities of particulates, sulfur and nitrogen oxides, carbon monoxide, carbon dioxide, and hydrocarbons. Of these, only sulfur oxides (principally sulfur dioxide) and non-hydrocarbon particulates will have significant impacts on solid waste generated from pollution control. Of the three fossil fuels, only coal combustion produces significant amounts of particulates. However, coal, oil, and, to a lesser extent, gas combustion all produce some sulfur oxide emissions. Discharges before treatment of particulates from power plants were forecast to increase from 33.6 billion kg in 1971 to 65.8 billion kg in 1985. Similar discharges of sulfur dioxide were forecast to rise at a more rapid rate, from 19.9 billion kg to 42.9 billion kg during the same period.

To control sulfur oxide and particulates generated from fossil fuel plants, three types of abatement measures may be used: low sulfur fuels (primarily for coal and to a lesser extent, for oil), throw-away flue gas cleaning systems, and three saleable by-product flue gas cleaning systems. The three main throw-away technologies are lime scrubbing, limestone scrubbing, and furnace injection (primarily dolomite). The three main saleable product systems are magnesium oxide scrubbing, the Wellman-Lord process, and catalytic oxidation. Considerable uncertainty exists pertaining to the industry-wide application of low sulfur fuels as throw-away systems vs. saleable by-product systems. Saleable product systems were forecast to account for 15 percent of total sulfur oxide emissions control by 1975, and for 20 percent by 1980 and through 1985. The treatment of radioactive wastes from nuclear power plants generally involves collection and storage for a sufficient time prior to disposal.

Solid waste from pollution control in electric power plants was forecast to increase from 25.6 billion to 135.5 billion kg between 1971 and 1985. The weight of solid wastes from nuclear power plants was forecast to increase from 730,000 kg to 23 million kg between 1971 and 1985; it is assumed that 100 percent control will be enforced throughout this period.

Sewerage Systems, SIC 4952 (Section XVII). The main source of pollutants discharged to the sewerage systems evaluated in this Section is municipal influent from the sewered population. Significant pollutants contained in this influent are solids, BOD_5,total nitrogen, and chlorides. Uncontrolled discharges for these pollutants in 1985 were forecast to be 6.6, 5.6, 1.4, and 2.8 billion kg, respectively. The impact of treatment methods on solid waste will greatly depend on subsequent disposal practices. Secondary treatments will produce more solid waste residues than primary treatments. Disposal methods that will have a significant impact on solid waste residues are primarily landfilling, with or without prior digestion, and to a lesser extent, incineration. The reuse potential for sewage sludge is great; agricultural or other land application is often feasible, depending primarily on the physiochemical nature of the sludge, but was forecast to remain stable through 1985.

Solid residues generated from water pollution control and subsequent disposal were forecast to increase to 2.8 billion kg in 1985, up 85 percent from 1.5 billion kg in 1971. The main factors responsible for this increase are the growth in sewered population and the increasing use of secondary, as well as primary, treatment between 1971 and 1985. The composition of the residues will be a function of the types of treatments applied to the sludge. Bacteria counts will be high in raw primary sludge, and digested sludges will have less volatile matter, greases and fats, and protein, and more ash and silica than either raw primary or secondary sludges. Sludge from urbanized areas will have a much higher concentration of heavy metals than that from rural areas, and thus be less suitable for land reuse.

Other Sources of Solid Wastes Generated by Air and Water Pollution Control (Section XVIII). Untreated discharges of relevant air pollutants from remaining sectors are mainly particulates (largely from paving and roofing materials, concrete, plaster, and gypsum production). Particulate emissions from all sectors evaluated are forecast to increase from 8.4 billion to 18.3 billion kg between 1971 and 1985. Sulfur oxide emissions were forecast to increase from 2.9 billion to 4.7 billion kg during the same period. BOD_5 andsuspended solids are the primary water pollutants affecting solid wastes. Textile mills account for a large portion of both these water pollutants, while the beverage industry also discharges significant amounts of BOD_5. Total BOD_5 discharges were forecast to increase from 450 to 660 million kg during this period. Particulate emissions from these assorted industries will be controlled by cyclones, filtration, baghouses and electrostatic precipitation; which specific treatments are used varies among the individual industries. Particulates trapped by pollution controls for most industries are capable of extensive reuse; reuse of residues derived from water pollution control, on the other hand, is minimal.

Total solid waste residues from pollution control were forecast to increase from 720 million kg in 1971 to 2,300 million kg in 1985. Textile mills, paving and roofing materials production, and incineration of municipal refuse are important contributors to these solid residues derived from pollututon control activities.

Hazardous Wastes from Air and Water Pollution Control (Section XIX). Radioactive wastes were projected to increase very rapidly as the result of the increasing use of nuclear power to replace limited fossil fuel supplies. The largest growth in the production of non-radioactive hazardous waste streams was projected to be from inorganic chemicals, synthetic drugs, organic chemicals, industrial machinery, electrical machinery, aircraft, and power utilities. The discharges were separated into aqueous inorganic solutions, aqueous organic solutions, sludges, and radioactive wastes. Because of the extremely diverse nature of these waste streams, no general statements could be made as to their composition. All the waste streams evaluated in this Section are far more damaging than their mass alone would indicate.

Non-radioactive hazardous wastes are subject to few controls at the present time, but may create increasing amounts of hazardous solid waste residues as advanced treatments are applied by 1985. Evaporation, neutralization, flocculation, sedimentation, carbon absorption and other treatments are all projected to increase in the future. In general, little reuse potential exists for most hazardous waste residues. Most radioactive wastes are solidified before final disposal.

The total known hazardous wastes from air and water pollution controls were projected to increase from 1,030 million kg in 1971 to 29,770 million kg in 1985. Well over 99 percent of this increase is attributable to the increased amounts of uranium tailings from uranium mines. Uranium tailing quantities were forecast to increase from approximately 30,000 million kg in 1985, a thirty-fold increase. Quantities of other hazardous solid residues derived from pollution control, in contrast, are much smaller in absolute value and show a much slower rate of increase between 1971 and 1985. Hazardous solid residues from inorganic and organic residues plus those from sludges were estimated to be approximately 33 million kg in 1971, to peak at 37.5 million kg in 1985, and to decline to approximately 36 million kg by 1985.

Non-radioactive hazardous solid residues, although of minor importance compared to radioactive hazardous solid residues in terms of weight, nevertheless present significant handling and disposal problems. In California, a landfill classification system is in effect which classifies those landfill sites environmentally suitable for hazardous waste disposal; this system is a promising method for informing hazardous waste generators where wastes may be properly disposed. Unfortunately, recent regulations have caused industrial confusion concerning acceptable disposal alternatives, resulting in the dangerous practice of storing hazardous residues on-site until disposal alternatives are further clarified.

Summary of the Costs of Pollution Control in the Major Discharging Sectors.

Costs of Specific Control Methods. Table XX-11 presents, for representative industrial processes in several sectors with a substantial effect on solid waste residues from air pollution control, estimates of (annualized) capital cost and operating cost for the following air pollution control processes:

(1) Cyclones

(2) Filters (including baghouses)

(3) Electrostatic precipitators

(4) Wet scrubbers

(5) Limestone injection

Table XX-12 presents similar cost information for the following water pollution control methods:

(1) Screening

(2) Sedimentation

(3) Flotation

(4) Activated sludge

(5) Trickling filters

(6) Lagoons and stabilization basins

(7) Chemical treatment (addition)

(8) Activated carbon

The cost figures--for controls on both air and water pollutants--should be interpreted as order-of-magnitude estimates varying with specified plant size, location, manufacturing processes and, of course, the given pollution control process. Available data were not adequate for a full assessment of the economic impact of required pollution controls on specific industries. Some specific industrial pollution economic data were found and evaluated, and are presented herein.

The Cost of Solid Waste Residue Disposal. Solid waste residues from air and water pollution control require ultimate disposal. Among the alternatives are:

(1) Sanitary landfilling

(2) Land disposal

TABLE XX-11

AIR POLLUTION CONTROL COSTS FOR REPRESENTATIVE INDUSTRIAL PROCESSES[11]

Source: (SIC Code)	Treatment Method: Pollutant Removed	Capacity	% Efficiency	Capital Cost	Operating Cost
Electric power prod., on-grate, high rate firing: (49)	Single cyclone: particulates		50-90		\$125-250/ 10^3 cfm
Electric power prod., coal, spreader stoker: (49)	Multicyclone: particulates		75-90		\$150-300/ 10^3 cfm
Lime prod., rotary kiln: (32)	High efficiency cyclone: particulates	@ 5 gr/ft^3, 60,000 cfm	84.2	\$17,600 or \$0.28/cfm	\$6,500/yr
Electric power prod., coal, small plant: (49)	Cyclone: particulates		65	\$100-200/ 10^3 cfm	
Concrete batching: (32)	Fabric filters: particulates	900,000 lb/hr		\$10,000	
Steel prod., electric arc furnace: (33)	Fabric filters: particulates	18T/heat furnace		\$45,000	
Concrete batching: (32)	Fabric filters: particulates	900,000 lb/hr		\$10,000	

TABLE XX-11 (Cont.)

AIR POLLUTION CONTROL COSTS FOR REPRESENTATIVE INDUSTRIAL PROCESSES[11]

Source: (SIC Code)	Treatment Method: Pollutant Removed	Capacity	% Efficiency	Capital Cost	Operating Cost
Gray iron foundry: (33)	Fabric filter: particulates	4000T/yr	92	$150,000	$5,000/yr
Steel prod: (33)	Fabric filter: particulates	25M plant-4 open hearths	92	$425,000	$40,000/yr
Electric power gen., coal-fired: (49)	Electrostatic precipitator: particulates		85-99	$300-1,000/ 10^3 cfm	
Steel prod. open hearth: (33)	Electrostatic precipitator: particulates	60T /heat furnace		$150,000	
Steel prod., open hearth furnace: (33)	Wet scrubber: particulates and SO_x	4 furnaces	40	$200,000	$30,000/yr
Typical performance	Impingement scrubber: particulates, SO_x	@ 5 gr/ft^3	97.9	$28,800 or 0.48/cfm	$10,500/yr
	Venturi scrubber: particulates, SO_x	@ 5 gr/ft^3	99.7	$42,000 or $0.70/cfm	$33,800/yr
	Disintegrator scrubber: particulates, SO_x	@ 5 gr/ft^3	98.5	$66,600 or $1.12/cfm	$66,500
Electric power prod., coal: (49)	Scrubber (soda ash solution):SO_2		75	$5.00/KW	$2.50/ton coal
Electric power gen., coal-fired: (49)	Limestone injection: SO_2	800 MW	90	$1.00/KW	$1.15/ton coal

TABLE XX-12
WATER POLLUTION CONTROL COSTS FOR REPRESENTATIVE INDUSTRIAL PROCESSES[11]

Source: (SIC Code)	Treatment Method: Pollutant Removed	Capacity	% Efficiency	Capital Cost	Operating Cost
Municipal sewage: (4952)	Screening: BOD_5, SS	10 mgd 21 mgd		\$440,000 \$2.07/capita	\$0.65/1000 gal \$0.17/capita/yr
Cannery effluents: (2033, 2037)	Activated sludge: BOD_5, SS	8 mgd	90	\$550,000	\$58,000/yr
Pulp mill effluent: (2611)	Activated sludge: SS, BOD_5	54 mgd	78	\$31,127,000	\$3,087,000/yr
Cannery waste: (2033, 2037)	Trickling filter: BOD_5	8 mgd	76	\$2,000,000	\$29,000/yr
Pulp mill effluent: (2611)	Lagoons & stabilization basins: BOD_5	17 mgd	80-95	\$665,000	\$111.20/mg wastewater
Petrochemical waste: (29)	Lagoons & stabilization basins: BOD_5	10 mgd			3.4¢/lb BOD_5 removed
Rinse water from steel pickling: (3312)	Chemical addition: Fe	1,500 gpm	99	\$1,360,000	4.38¢/fin steel-24¢/1,000 gal wastewater
Coal mining acid (12)	Chemical addition: Fe		99 96.2 97.2		Chemical cost: \$0.32/1,000 gal \$0.35-.059/1,000 gal \$.268/1,000 gal

TABLE XX-12 (Cont.)

WATER POLLUTION CONTROL COSTS FOR REPRESENTATIVE INDUSTRIAL PROCESSES[11]

Source: (SIC Code)	Treatment Method: Pollutant Removed	Capacity	% Efficiency	Capital Cost	Operating Cost
Coal mining (Cont.) acid mine drainage: (12)	Acidity (cold)		99.5 90.0 100.0		$0.32/1,000 gal $0.35-0.57/1,000 gal $.268/1,000 gal
Pulp & paper waste: (26)	Chemical addition:				
	COD	10 mgd	70	$.05/1,000 gal	op. = 5¢/1,000 gal
	PO_4 =		90		
	SS		40-80		chem = 6¢/1,000 gal
Municipal sewage: (4952)	Activated carbon:				
	SS	350 mgd	90	$39,439,000 16.7¢/gpd	$6,116,000/yr 95¢/1,000 gal
	BOD_5		85		

(3) Incineration with air pollution controls

(4) Open burning

(5) Ocean dumping

} environmentally unacceptable, but historical disposal methods

Before ultimate disposal several processes are commonly available to reduce the volume or mass of solid waste. These include:

(1) Composting

(2) Baling

(3) Shredding

Solid waste residues in aqueous (sludge) form may undergo stabilizing or volume-reducing treatments including:

(1) Drying or dewatering

(2) Oxidation

(3) Digestion

(4) Chemical stabilization

Table XX-13 presents cost estimates of these treatment processes and costs for transporting solid or sludge wastes. Table XX-14 lists alternative residue disposal techniques by residue media for various air pollution treatment methods. Table XX-15 presents alternative techniques by residue media for disposing residues from various water pollution treatment processes. The selection of a disposal method for solid waste residues must include consideration of both cost and environmental factors. This complicates the selection process since there is no generally accepted method of simultaneously evaluating environmental and social cost considerations. Where environmental standards exist, by legislative or administrative fiat, the selection process involves picking the least-cost alternative which meets the given air and water quality standards. Sanitary landfilling and land disposal are generally the most environmentally acceptable ultimate disposal alternatives.

Per unit disposal cost depends on the disposal technique chosen, distance to the ultimate disposal site, and the quantity of solid waste residues to be disposed. Table XX-13 presents approximate cost ranges for several alternative disposal techniques. These costs refer to disposal sites within a 25-mile travel distance. Figure XX-6 illustrates the effect of distance on disposal cost for rail, pipeline, and tank truck transport of residues. Rail transfer costs are the highest of the three, followed by truck and then pipeline. However, the marginal cost of rail transport for long distances is much lower than trucking, while pipeline transport is even less. Therefore, for short-distance hauling, rail is more expensive than trucking, but for long-distance hauling it is less costly than trucking. Figure XX-6 indicates that at a distance to disposal site of about 150 miles, rail transport becomes less costly than trucking. Pipelines may be less costly than either trucking or rail haul, but may require great capital investment.

TABLE XX-13

DISPOSAL AND TRANSPORTATION COSTS[11]

Method	Cost Range ($/ton)
Treatment	
Baling	3.00 - 5.00
Shredding	3.50 - 6.00
Drying	40.00 - 50.00
Oxidation	30.00 - 50.00
Digestion	20.00 - 30.00
Chemical stabilization	--
Composting	5.00 - 10.00
Disposal	
Incineration[a]	10.00 - 30.00
Open burning[b]	0.05 - 0.25
Sanitary landfilling	0.75 - 6.00
Land disposal	1.25 - 7.00
Ocean dumping[b]	0.10 - 2.00
Transportation[c]	
Truck to land	20.00 - 50.00
Barge to sea	10.00 - 20.00
Pipeline to land	5.00 - 20.00
Water outfall	3.00 - 5.00
Rail to land	30.00 - 100.00

[a] With pollution control costs included.

[b] Common historical practice, but may have adverse environmental impact.

[c] Short-distance transporting -- under 25 miles.

TABLE XX-14
AIR TREATMENT RESIDUE DISPOSAL TECHNIQUES[11]

Treatment	Residue Media	Residue Disposal Method
Cyclones	Land	Dry removal and disposal to landfill
	Water	Flush with water
	Air	Incineration of wastes
Activated carbon	Land	No regeneration - disposal of saturated carbon
	Water, land	Periodic disposal of spent carbon Some contaminated sludge from regeneration goes to water
Flares	Air	No residue collection - completes combustion process
Filters	Land	Dry removal of residues - vibration unusual but residues vibrated into a hopper
	Water	May be flushed with water
	Air	Incineration of wastes
Electrostatic precipitator	Land	Dry removal of residues to landfill
	Air	Incineration of wastes
Gravity settling chamber	Land	Dry removal
	Water	Flush residues with water
	Air	Incineration of wastes
Scrubbers	Water	Process water to sewer or stream
	Land	Lime slurry treatment - removes calcium fluoride, calcium sulfate, etc. on settling ponds
Water spray	Water	A type of scrubber - water directly to water body
	Land	Lime slurry treatment for removal of calcium fluoride, calcium sulfate, etc. on settling ponds
Afterburner	Air	No removal - complete combustion products

TABLE XX-14 (Cont.)
AIR TREATMENT RESIDUE DISPOSAL TECHNIQUES[11]

Treatment	Residue Media	Residue Disposal Method
Furnace limestone injection	Land	Sulfate residues removed as slag
Fuel additives	Air	Facilitate complete combustion
Vapor control systems	None	Retention of vapors in original solution
Burner cans for planes	Air	Complete combustion process

TABLE XX-15
WATER TREATMENT RESIDUE DISPOSAL TECHNIQUES[11]

Treatment	Residue Media	Residue Disposal Method
Screening	Land	Disposal to landfills
	Air	Incineration
Activated sludge	Land	Landfills, or agricultural application
	Water	Pumping to ocean or other water body
	Air	Sludge incineration
Trickling filter	Air	NH_3, NO_2, NO_3 liberated by bacterial and enzyme action
	Land	Disposal to landfill of settled material
	Water	Pumping of settled slurry to sea or other water bodies
	Air	Incineration of settled material
Lagoons and stabilization ponds	Air	Escape of gases from decomposition process
	Water	Nondecomposed overflow from lagoons
	Land	Periodic dredging of settled inorganics
Chemical addition	Land	Sedimentation of coagulated material
Stripping towers	Air	Release of NH_3 by alteration of surface tension
Sedimentation	Land	Disposal to landfill or agricultural application
	Air	Incineration of residues
Flotation	Land	Disposal to landfill or agricultural application
	Air	Incineration of residues
Electrodialysis	Land	Evaporation of slurry - landfill disposal
	Water	Flushing of membrane with water. Process water cleaned and slurry to sewer or water body
Activated carbon	Land	Disposal of saturated carbon
	Water	Carbon regeneration with steam

TABLE XX-15 (Cont.)
WATER TREATMENT RESIDUE DISPOSAL TECHNIQUES[11]

Treatment	Residue Media	Residue Disposal Method
Ion exchange	Land Water	Evaporation and disposal of slurry Regeneration of resin. Recovery of nitrogen and other adsorbed material from regenerant salt solution (negligible)
Reverse osmosis	Land Water	Evaporation and landfill disposal Flushing membrane with water - slurry to ocean or water body
Spray irrigation	Land	A residue disposal technique - waste application to agricultural land
Chlorination	None Air	Use for disinfection of wastewater Ammonia, nitrogen wastes converted to nitrous oxide - released to atmosphere Oxidation and breakdown of organic material
Prevention of dumping of hazardous wastes	Land	Landfill disposal of hazardous chemicals
Sewage sludge, drying or digestion	Land Air	Landfill disposal of dry/digested material Gases given off by drying or digestion process

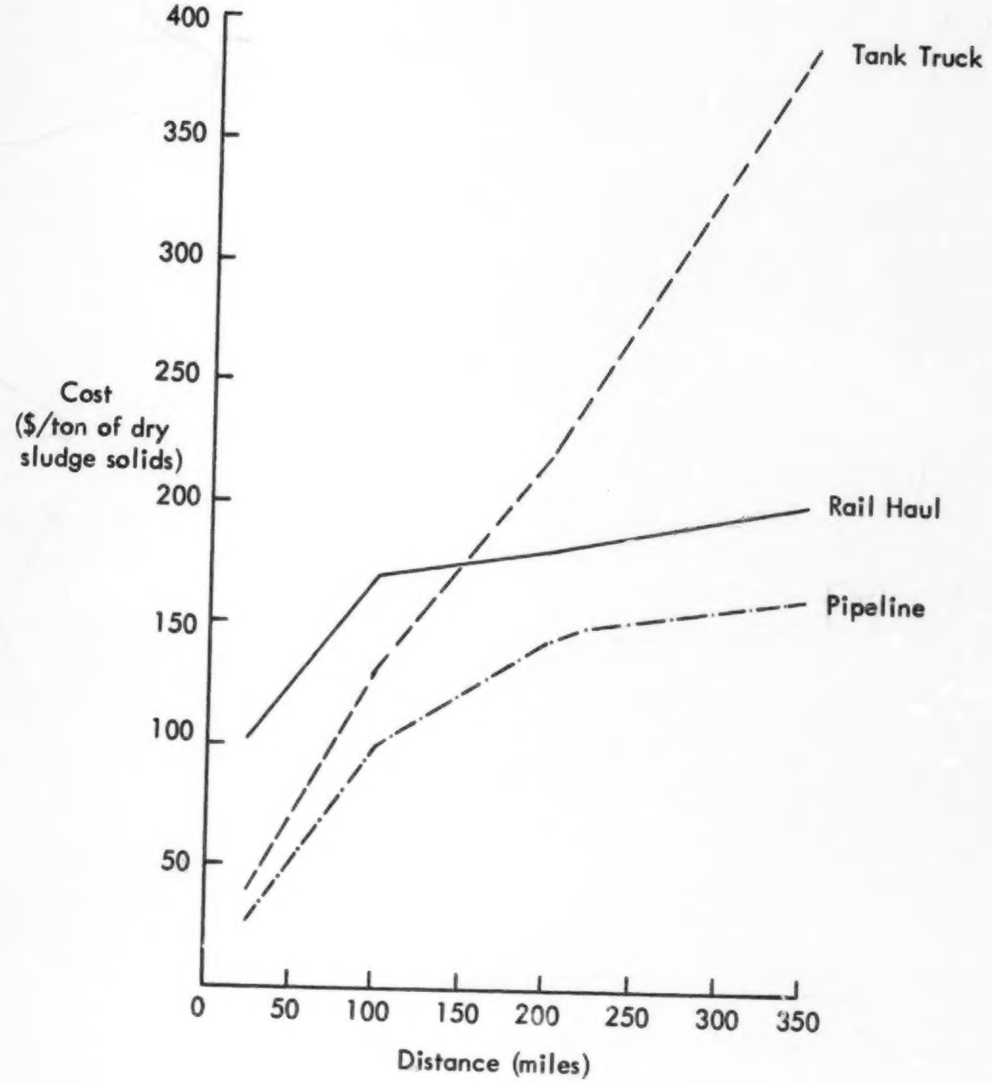

FIGURE XX-6
RESIDUE DISPOSAL COSTS AS A FUNCTION
OF DISTANCE TO DISPOSAL SITE[11]

Impact of Air and Water Pollution Controls on Production Costs. This section examines the effect that required improvements in pollution controls are likely to have on production costs in major polluting sectors. The incidence of the increased cost (who pays) is not discussed. Incidence depends on several factors, including domestic market structure, availability of acceptable substitutes, international market conditions, and demand and supply elasticities. Depending on these factors, the cost of pollution control may result in higher prices to consumers, lower profit to domestic producers, plant closings, market shifts to foreign producers, or other changes.

Table XX-16 presents estimates for selected industries of cost increases from pollution controls. Forecast increases range from under 2 percent to over 10 percent. These are industry averages and greater diversity can be expected for individual plants - especially older, smaller, less efficient plants. The impacts of required controls are forecast to vary by industry. Particularly large increases appear possible for power plants and paper production.

TABLE XX-16

THE IMPACT OF POLLUTION CONTROLS ON PRODUCTION COSTS FOR SELECTED INDUSTRIES

Sector	Water Pollutant Control		Air and Water Pollutant Control		Reference
	Year	Production Cost Increase (%)	Year	Production Cost Increase (%)	
Cement	1985	1.5[a]			260
			1976	4.5	14
Paper	1977	3.0 - 7.0			437
			1976	3.5-10.0	14
Power plants	1977	2.3[f], 1.6[g]			438
	1983	4.7[f], 2.5[g]			438
			1976	2.8-11.0[b]	14
Steel	1983	1.7			439
			1976	1.5-4.0	14
Nonferrous			1976	5.0-8.0[e]	14
			1976	8.0[d]	14
			1976	5.0[e]	14
Petroleum refining			1976	1.4	14
Chemicals	1977	2.4-10.9[h]			440
	1977	0-14[i]			252

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[a] Assuming full-capacity operation.

[b] Depending on the type of fossil fuel used.

[c] Aluminum smelting and refining.

[d] Copper smelting and refining.

[e] Zinc smelting and refining.

[f] Before exemptions.

[g] After exemptions.

[h] Fertilizer industry; estimate depends on plant capacity and product.

[i] Inorganic chemicals; depends on product produced.

SECTION XXI

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SECTION XXII

GLOSSARY

Abbreviations Used in the Study.

Common Elements

Al	Aluminum
Ca	Calcium
Cu	Copper
Fe	Iron
N	Nitrogen
O	Oxygen
P	Phosphorous
S	Sulfur
Zn	Zinc

Measures of Energy

BTU	British thermal unit
GWH	Gigawatt-hour (10^9 watts for one hour)
kcal	Kilogram-calorie (3.9685 BTU)
kwh	Kilowatt-hour (10^3 watts for one hour)
MW(e)	Megawatt of electrical energy (rate)
MW(t)	Megawatt measured as thermal energy (rate)
MWh	Megawatt-hour (10^6 watts for one hour)
mw	Milliwatt

Measures of Weight

kg	Kilogram
kkg	Metric ton (10^3 kilograms)
mg	Milligram

SECTION XXII (Cont.)

GLOSSARY

Measures of Volume and Length

Gal	U.S. gallon
l	Liter (.2642 U.S. gallons)
m^3	Cubic meter
bbl	Barrel
μ	Micron - (10^{-6}m)
cm	Centimeter
m	Meter

Measures of Radioactivity

Ci	Curie-measure of radioactivity in which 3.7 x 10^{10} disintegrations per second occur.
μc	Microcurie (10^{-6} curies)

Pollutants

BOD_5	Five day biological oxygen demand
SS	Suspended solids
TDS	Total dissolved solids
TS	Total solids

Miscellaneous Industrial and Economic Abbreviations

lwk	Live weight of animals killed in slaughterhouses
GNP	Gross national product
FRB	Federal Reserve Board
PWR	Pressurized water reactor (nuclear power plant)
BWR	Boiling water reactor

Radioactive Isotopes

Co^{60}	Cobalt 60, half life of 10.7 months
Cs^{134}	Cesium 134, half life of 3.15 hours

GLOSSARY

Radioactive Isotopes (Cont.)

H^3	Tritium, half life of 12.5 years
Pm^{147}	Promethium 147, half life of 2.26 years
Po^{210}	Polonium 210, half life of 138 days
$Pu^{238,239,240,241}$	Plutonium 238, 239, 240, 241; half lives of 92, 24,100, 6,580, and 14 years
Ra^{226}	Radium 226, half life of 1,620 years
Rn^{222}	Radon 222, half life of 3.825 days
Ru^{106}	Ruthenium 106, half life of 1 year
Sr^{90}	Strontium 90, half life of 28 years
Th^{230}	Thorium 230, half life of 80 years

Conversion Factors from English to Metric Units

1 kg/metric ton = 2 lbs/short ton

1 metric ton = 1.1022 short tons

1 liter = .2642 gallons (U.S.)

1 m^3 = 35.34 cubic feet

1 kcal = 3.9685 BTU

Definitions of Terms Used in the Study

General Terms

Head-day	One day spent in a feedlot by one cow, chicken, steer, etc.
Intermedial	A pollutant capable of transfer between air-water-land media
Intramedial	A pollutant incapable of transfer between media
kg head-day	One day spent in a feedlot by one animal weighing one kg
Media	The media (air, water, or land) in or on which a pollutant is found
Pollutant	Any material which may contribute to environmental degradation and thus must be controlled
Reuse	The reclamation or use of a solid residue or waste product for beneficial purposes
Solid waste residue	Solid material left over from a pollution treatment process. Solid waste residue may or may not be in solid form; in fact, many residues are dissoved or suspended in a liquid medium

SECTION XXII (Cont.)

GLOSSARY

Definitions of Terms Used in the Study (Cont.)

Solid waste	For specifically forecasting purposes, solid waste residues for which no economic opportunity for reuse exists; more generally, wastes destined primarily for land disposal
Treatment process	Method of eliminating a pollutant or transferring it to another media

Water Pollutants

Biological oxygen demand	The amount of oxygen used up by the natural decomposition of waste matter usually measured as the amount demanded in 5 days (BOD_5)
Pickle liquor	Waste liquid from pickling of mill scale in steel mills
Suspended solids	Solids in water which are not in solution. Unless otherwise indicated in this study it will include settleable and flotable solids
Total dissolved solids	Total solid material in a dissolved state in water
Total solids	Suspended plus dissolved solids

Air Pollutants

Ammonia	NH_3, a gaseous air pollutant
Carbon monoxide	CO, an intramedial air pollutant, controlled by conversion to CO_2
Fluorides	Various fluorine compounds which may be in gaseous or particulate form
Hydrocarbons	Particulate and gaseous hydrocarbons. Particulate hydrocarbons are included with the measure of particulates
Hydrogen sulfide	H_2S
Nitrogen oxides	NO, NO_2, NO_3, almost a completely intramedial pollutant, predominantly NO_2

GLOSSARY

Air Pollutants (Cont.)

Sulfur oxides	SO_2, SO_3, predominantly SO_2; is capable of generating large amounts of solid residues when treated with lime scrubbing methods followed by sedimentation
Particulates	Solid particles of all types emitted into the air and capturable by filters

SECTION XXIII

APPENDICES

Page

A. Reconciliation of estimates of air pollutant emissions XXIII-2

B. Reconciliation of estimates of water pollutant emissions made in previously published studies XXIII-24

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APPENDIX A

RECONCILIATION OF ESTIMATES OF AIR POLLUTANT EMISSIONS

Introduction.

At the beginning of the current study, a reconciliation was made of various published estimates of all individual SIC code air and water pollution discharges for 1971, or where not available for 1971, the years closest to that year. These reconciliations for air and water pollutants are included in this (A) and the following (B) Appendices.

The reconciliations were performed on two levels of detail. Data for all industries for the major air pollutants were first reconciled using various data sources. Then, data for the air pollutants most relevant to the present study, sulfur oxides and particulates, were examined in greater depth for certain key industries resulting in final estimates of uncontrolled discharges; these sometimes differed from the original reconciled estimate.

Preliminary Reconciliation.

Since the Economics of Clean Air report (ECA) is the most comprehensive and detailed of the available Federal estimates of air pollution on a National scale, it was used as a starting point; the emissions given for 1967, and the emissions predicted for 1976 with 1967 control levels, were used to estimate by interpolation the amounts of emissions in 1971. The independently-made "Intermedia[1]" estimates and estimates from other sources were compared with ECA-based estimates.

The EPA Intermedia Study used 1971 as the base year. Where there was a significant difference between the estimates and where no clear reason existed to substantiate the accuracy of a particular source, the ECA data were used for the current study. Where the ECA estimates clearly contained errors or omissions, alternative estimates were made. For instance, the ECA estimates for Sector 331, blast furnaces and basic steel production, contained no estimate for pig iron production emissions. Here the figures from the EPA Intermedia study were used to supplement the data from the ECA study.

Table A-2 contains the lists of the original estimates from the alternative sources and the preliminary estimates made for controlled emissions, uncontrolled emissions, and control levels. Where the criteria for the derivation of these estimates are not clearly shown in Table A-2, they are explained in Table A-3. The total controlled and uncontrolled figures presented at the bottom of Table A-2 are totals of these respective columns. Where a figure was available in only one of the two columns, it was nevertheless used in the calculation of both totals. Table A-1 presents the reference abbreviations used in Appendices A and B.

TABLE A-1

REFERENCE ABBREVIATIONS: APPENDICES A AND B

Abbreviation	Meaning
RSI	Stone, R., and Smallwood, H.,[11] Intermedia Aspects of Air and Water Pollution Control
ECW	The Economics of Clean Water[66]
FWPCA	Federal Water Pollution Control Administration
SIC	Standard Industrial Classification
ECA	Economics of Clean Air, 1971 and 1972
CEQ	Council on Environmental Quality, Environmental Quality
COE	Cleaning Our Environment

TABLE A-2

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Particulates

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Vandegrift	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
01	---							
08	249					249		
10	11,567					11,567	864	92.5
11,12		246				585	247	58
14	7,033	435	4,173			7,032		
201, 202	---					---		
204	1,512	1,342	1,542			1,964	1,342	32
20	1					1		
22	92					92		
24	15(P)[a]					15(P)		
26	3,016	401				2,676	379	85
281	20	27				3,974	48	88
2874		269				2,440	269	89
2895	850		84			850	132	84
291	440	188				440	352	20
295	484	220				4,400	220	95
30		1				5	1	80
324	6,633	772	847			9,616	772	92
325	196		425			1,089	425	61
327	3,582					3,582		
331	9,829	1,980				9,829	1,080	89
332	685	212				685	603	12
333	166	332				1,544	332	76

TABLE A-2(Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Particulates

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Vandegrift	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
334	171	25	115			158	115	27
336	30					30		
40	44					44		
42	267					267		
45	21					21		
491	2,722[b]	3,883	2,812		2,722	17,690	3,883	78
4953	1,270			1,270	907		1,270	
5541	460	342		635	907	342		
Totals	51,355	19,109	16,403[a]	23,042	10,886	82,646	24,048	
Non-specific sources not cited above:								
Stationary fuel combustion		7,074		6,169				
Industrial processes				11,884	5,443			
Misc.		1,321	6,405	3,084	907			

[a] Controlled emissions from major industrial sources only.

[b] Controlled emissions.

TABLE A-2(Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Hydrocarbons

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
01	---				---		
08	806				806		
24	6(P)				6(P)[a]		
281	560				560		
282	15				15		
2851	-	1			1	1	18
2895	447				447		
291	1,372	1,209			2,302	1,209	48
331	1,080				1,080		
34	5				5		
36	15				15		
40	89				89		
42	685				685		
45	285				285		
491	58			907	58	58	0
4953	1,814		1,814	907	1,814		
5541	15,160	14,515	17,775[b]	10,886	22,271	14,515	35
Totals	22,397	17,552	31,564	17,236	30,439	21,590	

---

[a] (P) means partial data.

[b] all transportation.

TABLE A-2 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Hydrocarbons

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
Non-specific sources not cited above:							
Industrial processes			4,990	3,629			
Stationary fuel combustion			544	907			
Misc.		1,827	6,441				

TABLE A-2(Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Carbon Monoxide

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
08	953				953		
10					712		
201, 202	---				---		
26	1,396				1,396		
281	1,245				1,245		
2895	2,513				2,513		
291	13,959	9,453			11,816	9,453	20
331	534				534		
332	910	3,121			3,801	3,121	18
40	125				125		
42	3,600				3,600		
45	1,729				1,729		
491	90			907		90	
4953	6,532		6,532	907	6,532		
5541	78,734	90,720	100,699	59,875	125,193	90,720	28
Totals	112,320	108,621	133,540	65,317	160,239	122,723	21.5

TABLE A-2 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Carbon Monoxide

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
Non-specific sources not cited above:							
Industry			10,342	1,814			
Space heating				1,814			
Stationary fuel combustion		5,327	726				
Miscellaneous			15,241				

TABLE A-2 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Sulfur Oxide

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
11	---				---		
12	---				---		
26	100				100		
281	531	660			22,013	660	97
291	2,177	2,350			3,724	2,349	37
331	453				454		
333	3,371	3,236			4,377	3,236	26
40	98				98		
42	290				290		
45	10				10		
491	18,144	9,199		10,886		13,608	0
4953	91		91	907	91	91	
5541	2,516			907	2,516		
Totals	27,781	41,316	30,754	23,586	47,281	23,412	
Non-specific sources not cited above:							
Transportation			907				
Stationary fuel combustion		25,684	24,041				
Industrial processes			5,443	8,165			
Misc.		187	272				
Heating plants (Commercial) (Institutional)				2,721			
Residential heating plants							
Industrial boilers							

TABLE A-2 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF AIR POLLUTION

Pollutant: Nitrogen Oxides

Thousands of Metric Tons

SIC	R.S. and Co. Intermedia	Economics of Clean Air (ECA)	Council on Env. Quality (CEQ)	Cleaning our Environment (COE)	Uncontrolled	Controlled	% Control
291	273				273		
327	15				15		
332	4				4		
40	133				133		
42	4,238				4,238		
45	30				30		
291	---			2,722	2,722		
491		4,953				4,953	0
4953	363		363	907	363		
5541	6,797	7,257		5,443	7,257	7,257	0
Totals	11,853	20,409	20,592	11,793	19,988	19,988	
Non-specific sources not cited above:							
Transportation		20,569	10,614				
Stationary fuel combustion		7,838	9,072				
Industrial processes		162	181	1,814			
Misc.		359	362				
Space heating				907			

TABLE A-3
DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Particulates

SIC#	Derivation of Final Estimate[a]
01	Particulates are generated by agricultural burning, but no quantitative information was available.
08	RSI is the only available source of information.
10	The major uncontrolled source is sintering, which was omitted from RSI. ECA included it within the overall estimate for the iron and steel industry. The 1972 SIC manual includes it in Sector 10, Metal Mining. 19 kg particulates per ton of sinter (RSI ref 278) x 32.5 x 10^6 (RSI ref. 357) yields 11,385 kg. At 94 percent control emissions are 682 x 10^6 kg; Vandegrift also estimates that 362 x 10^6 tons of particulates are emitted from uncontrolled bauxite grinding and copper, zinc, and lead or crushing operations. All these sources are equivalent to 864 x 10^6 kg with 92.5% controls.
11,12	ECA data on coal cleaning is the only available source of information.
14	The RSI data are the most comprehensive. ECA only accounts for lime. Vandegrift only accounts for crushed stone, sand and gravel. The RSI data were used. The overall control level is not known.
201, 202	No reliable sources were found.
20,22,24	RSI is the only available source of information.
261	ECA is the only available source of information.
281	RSI was the only source of information for particulates from phosphoric acid manufacture (20 x 10^6 kg). ECA was the only source for particulates from sulfuric acid plants (27 x 10^6 kg at 88% control). 20 + 27 = 47 x 10^6 kg/year, assuming 88% control for phosphoric acid as well.
2895	RSI was the only accurate source. Oil and gas furnaces produce particulates at a rate of 1100 kg/ton of carbon black, and the channel process produces 1150 kg/ton, yielding 850 x 10^3 controlled,and 132 x 10^3 tons controlled (84%) control). Vandegrift underestimated emissions by ignoring particulate emissions from oil and gas furnaces.
291	ECA ignores part of the sector.

TABLE A-3 (Cont.)

DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Particulates

SIC#	Derivation of Final Estimate
491	RSI figures are based upon a very rough estimate for the breakdown of furnace types. The ECA figures were used assuming the control level of 78%.
4953	The figures are actual amounts of emissions. The control level is not known.
5541	RSI figures were based on California emissions tests. ECA figures are based on national emission tests and should be more accurate. No controls are assumed.

TABLE A-3 (Cont.)

DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Hydrocarbons

SIC No.	Derivation of Final Estimate
08	RSI is the only available source of information. 25-30 lb of hydrocarbons/ton of vegetation burned in a forest fire x 29.3 $\times 10^6$ tons burned in forest fires equals 806 $\times 10^6$ kg hydrocarbons.
24	Partial data. This only includes pollution from plywood manufacture. Open or teepee burning of saw mill wastes yields hydrocarbon emissions, but no information is available on the amounts of waste burned.
281, 282	RSI is the only available source of information. The RSI figure comes from the manufacture of purge gas.
282	1965 estimate.
2851	ECA is the only available source of information.
291	The ECA data give a figure of 1,054 $\times 10^6$ kg of hydrocarbons emitted by refining with 50% control, and a figure of 155 $\times 10^6$ kg for hydrocarbons evaporating from storage, with 20% control. The weighted average of 1,054 at 50% control and 155 with 20% control is the figure given for Sector 291, and is 1,209 kg at 48% control.
295-45	RSI tables were the only available sources of information for these estimates. The control levels were not known.
491	The RSI estimates are based on a very detailed government study (RSI ref 278) showing 9.5 kg HC/10^9 kcal in coal combustion, 636 kg HC/10^6 m^3 in gas furnaces, and 0.6 kg HC/1,000 liters oil in oil furnaces in the power industry.
4953	The RSI figure was taken directly from RSI references 14 and 90, the 1970 and 1971 CEQ reports.
5541	The ECA figure, 14,515 kg is based on a national average; the RSI figure, 15,162, was derived by extrapolating from the average California car. The final estimate for Sector 5541 is 14,515, which at 35% control (ECA) is equivalent to 22,271 kg uncontrolled emissions.

TABLE A-3 (Cont.)
DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Carbon Monoxide

SIC #	Derivation of Final Estimate
08-2895	RSI is the only available source of information.
10	22 kg CO/ton sinter (RSI ref. 278) times 32.5×10^6 tons sinter (RSI ref. 357) = 712×10^6 kg (not included in original RSI calculations.)
291	RSI assumes that one-half of 1.595×10^6 bbl is processed by fluid catalytic cracking, that the other half is processed by moving-bed catalytic cracking, and that the CO emissions are not controlled. ECA apparently has knowledge of the actual proportions of the bbl refined by each process, and estimates a 20% control. The ECA estimate is considered final.
295,331	RSI is the only available source of information.
332	Both RSI and ECA base their calculations on 12.7×10^6 tons of gray iron produced, mainly in the cupola furnace. However, the CO production in RSI is 72.5 kg/ton gray iron with no control (as given in RSI ref. 278), while the CO production rate in ECA is at least 3 times as high, with approximately 18% control. The ECA figure is used for the final estimate.
40,42,45	RSI is the only available source of information.
491	The COE estimate is for 1965. In recent years combustion processes have been better controlled. The RSI figure is a very rough approximation.
4953	COE estimate is for 1965 and seems to be understated.
5541	RSI figure is based on the average California car. Hence, the ECA figure is probably more accurate.

TABLE A-3 (Cont.)

DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Sulfur Oxides

SIC #	Derivation of Final Estimate
26	RSI is the only available source of information.
281	The amounts of sulfuric acid produced are the same in RSI and ECA, 26×10^6 tons. However, the SO_x production coefficient in RSI is 20 kg/ton sulfuric acid, while that in ECA is 26 kg/ton. The RSI coefficient was taken from RSI ref 278. The ECA figure and 97% control level were used for the final estimate.
291	The RSI figure was taken directly from RSI reference 376 (1970). The ECA percent control and figure were used to estimate the uncontrolled amount of SO_x.
331	RSI is the only available source of information.
333	The ECA figure, 3,236, has a control level of 26% and, hence, the uncontrolled level is approximately 4,377 million kg.
40,42,45	RSI is the only available source of information.
491	The final estimate is an average of the 9,072 given in ECA, and the 18,144 given in RSI (from RSI ref. 376).
4953	RSI figure was taken directly from RSI ref. 14, which is the 1972 CEQ report.

TABLE A-3 (Cont.)

DERIVATION OF ESTIMATES IN TABLE A-2

Pollutant: Nitrogen Oxides

SIC #	Derivation of Final Estimate
291-45	RSI was the only available source of information.
491	COE figure is a 1965 estimate. Hence ECA figures were used for the final estimate.
5541	The ECA figure is probably more accurate, since the RSI figure is an extrapolation from California condition.
4953	The RSI figure was taken directly from RSI ref. 14.

[a] All tons are metric tons
kg = kilogram
kcal = kilocalorie
m^3 = cubic meter
l = liter

Final Estimate of Uncontrolled Discharges for Key Industries.

Total particulate and sulfur oxide emissions before treatment are summarized in Table A-4 along with other air pollutants used in this study for the determination of solid waste residues from air pollution control. The sectors for which significant discrepancies exist between the final estimates of pollutant emissions made for this study and the preliminary reconciliation of previous studies (from Table A-2) are explained in the footnotes to Table A-4.

In general, fairly good agreement was achieved, some exceptions notwithstanding. The increased estimates for grain mills and paper and allied products were the result of a more detailed analysis of these sectors. The increase in the estimate of power plant particulate emissions was due to an independent estimate of trends in power generation fuels and systems. The estimates in Table A-2 for the sectors categorized under "Other Miscellaneous Sectors", were used unaltered as the final estimates for this study as the scope of this study prohibited a more detailed study of these sectors.

TABLE A-4

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

		Particulates		Sulfur Oxides		Other		
SIC	Description	Final	Prelim.	Final	Prelim.	Pollutant	Final	Prelim.
10,11,12,14	Mining	8,000	7,979					
203	Canned and preserved fruits and vegetables	0.74	--					
204	Grain mills	4,870[a]	1,964					
26	Paper and allied products				100			
						H_2S	272	
						Mercaptans	113	
		5,380[b]	2,676					
						SO_2	100	
						Color	868	
28	Chemicals and allied products	5,840	3,687					
						HC	466	
						CO	3,311	
						F	81	
				530[h]	22,013			
13,291	Petroleum refining, extraction, and transportation	300	440	3,480	3,724			
Key Industries:								
324,325	Cement and clay	10,910	10,705					

TABLE A-4 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

		Particulates		Sulfur Oxides		Other		
SIC	Description	Final	Prelim.	Final	Prelim.	Pollutant	Final	Prelim.
Key Industries (Cont.)								
331	Blast furnaces and basic steel	14,430[c]	21,214		454			
332	Iron foundries (and ferroalloys)	470	685					
333,334	Primary and secondary nonferrous smelting and refining	1,420[d]	1,702	4,740	4,377			
491	Power plants	33,600[e]	17,690	19,900[f]	13,608			
Other Misc. Sources:								
08	Forestry	250	249					
20	Misc. food products	1	1					
22	Textile mill products	90	92					
24	Lumber and wood products	15	15					
295	Paving and roofing materials	4,400	4,400					
30	Rubber and misc. plastics	5	5					

TABLE A-4 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

		Particulates		Sulfur Oxides		Other		
SIC	Description	Final	Prelim.	Final	Prelim.	Pollutant	Final	Prelim.
Other Misc. Sources: (Cont.)								
327	Concrete, gypsum and plaster	3,580	3,582					
336	Nonferrous foundries	30	30					
40	Railroad transportation	40	44	100	98			
42	Trucking and warehousing	270	267	290	290			
45	Air transportation	20	21	10	10			
5541	Automobiles	350	342	2,520	2,516			
4453	Solid waste disposal	2,802	1,270		91			
	Total	94,650	79,249	31,570	33,673			

TABLE A-4 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

[a] The original reconciliation used data from Vandegrift[10] which understated the amount of grain handled by a factor of two. The emission factors in the final estimate were taken from the Compilation of Air Pollutant Emission Factors[169] and were slightly different from Vandegrift's.

[b] The data in appendix C are from the Economics of Clean Air using 1967 production figures for sulfate pulping only. The final estimate in the current report updated the production to 1971 and considered all pulping processes assuming similar particulate emissions for sulfite and neutral pulping.

[c] The data in appendix XIII-3 include 11,385 x 10^6 kg from sintering and 9,829 x 10^6 kg for furnace operations, totalling 21,214 x 10^6 kg. The Economics of Clean Air estimated 2,091 x 10^6 kg from sintering and steel furnace operations at 55 percent control in 1967. These data conflicted, so that an independent estimate was made for this study including coking, sintering reduction, steel furnaces, scarfing, and materials handling. This totals to 14,431 x 10^6 kg.

[d] The data in appendix XIII-3 are from the Economics of Clean Air. The final estimate for this report used emission factors from Compilation of Air Pollutant Emission Factors and the output data in Table XV-4, except for zinc which was calculated using the emission factor in the Economics of Clean Air which was higher than the factor in Compilation of Air Pollutant Emission Factors.

[e] The data in appendix C is based on the Economics of Clean Air updated to 1971 assuming the 78 percent control level for the figure cited in order to convert to uncontrolled emissions. The final estimate used in the current report uses the emission factors from Compilation of Air Pollutant Emission Factors, which tend to be higher, and an independent estimate of output by fuel type as shown in Table XVI-9. This results in a higher estimate than in The Economics of Clean Air, which, it should be noted, contained different estimates by a factor of 2 in its 1971 and 1972 editions.

TABLE A-4 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF AIR POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

[f] The final estimate is based on 2.5 percent sulfur fuels. The data in Appendix C do not specify sulfur content. Because of unknown fulfur content in U.S. fossil fuel reserves, any estimate is necessarily subject to variation.

[g] Includes only particulates captured by emission controls on incinerators.

[h] Counted only 3 percent of sulfur oxides escaping absorption tower as untreated discharges as the absorption tower is part of the production process.

APPENDIX B

RECONCILIATION OF ESTIMATES OF WATER POLLUTANT EMISSIONS MADE IN PREVIOUSLY PUBLISHED STUDIES

Introduction.

Appendix B contains preliminary reconciliations and final estimates of uncontrolled discharges of water pollutants. These estimates were derived in a completely analagous manner to those appearing in Appendix A for air pollutants.

Preliminary Reconciliation.

Since the Economics of Clean Water report (ECW) is the most detailed of the available Federal estimates of water pollution contributions by Standard Industrial Classification (SIC) codes, extrapolations from ECW were used to compare estimates from the EPA Intermedia study and other sources. Unfortunately, most of the data in ECW refers only to BOD and SS, for SIC Sectors 20 to 39; furthermore, some of the data consisted of only sub-sectors within a three-digit sector, requiring extrapolation to the whole sector on the basis of ratios between production employees in the ECW subsector and production employees in the whole national sector. A similar difficulty was found when extrapolations were made on the basis of wastewater flow ratios; but in addition, few of the industrial plants in each SIC sector surveyed by ECW gave data on their wastewaters. The number was usually 1 to 8, commonly 1 or 2. Extrapolations made on wastewater bases were thus likely to be highly inaccurate and of marginal utility.

ECW presents data on "actual" BOD and SS production, as self-reported by the industrial plants themselves; no impartial field measurements were performed. Hence, the data in ECW must be critically compared to and supplemented with data from other sources, and especially from the EPA Intermedia study.

Table B-1 contains the lists of original estimates from different sources and final estimates made for this Project for both controlled and uncontrolled pollutant productions and control levels. The ECW column refers to extrapolations made on the basis of production employees. When figures are derived from ECW wastewater data, they appear in the column labelled "Other".

Where no information as to the control level is available, the estimate is listed in the "Uncontrolled" column. Where the criteria for the derivation of the final estimate are not clearly shown in Table B-1, this derivation is explained in Table B-2.

The total controlled and uncontrolled figures are the totals of these respective columns for the final estimates. Where a figure was available in only one of the two columns, it was used in the calculation of both totals.

TABLE B-1

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: BOD$_5$		Thousands of Metric Tons Per Year						
				. . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
02	Agric. Livestock			2000	16,17,95	2000		
201, 202	Meat Products and Dairy Products	1042	307	2426 2262	12,18 12,18	2426	2262	7
203	Processed Fruits and Vegetables	448	390	376	96	405		
204	Grain Mill Products		109	135	66	109		
208	Beverages		445	680	19	445		
20	Miscellaneous Food Products	22	11	36	13	47		
22	Textile Mill Products	399	213	436	93	348		
26	Paper and Allied Products	3583	1739	1288	97	1509		
281	Industrial Inorganic Chemicals	214[a]	204			204		

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: BOD_5		Thousands of Metric Tons Per Year				Final Estimate		
				. . . . Other				
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
282	Plastic Materials and Synthetics	263[a]	249			249		
283	Drugs	11[a]	11			11		
2873	Nitrogenous Fertilizers	3				3		
2879	Agricultural Chemicals nec	26				26		
28	Misc. Chemicals	45[a]	45			45		
291	Petroleum Refining	122	99	132	90	122		
31	Leather and Leather Products	85				85		
331	Blast Furnace and Basic Steel Production	108[a]	108			108		
332	Iron and Steel Foundries	6	6			6		
333	Primary Non-Ferrous Metals	2	2			2		
335	Non-Ferrous Drawing, Rolling and Extruding	3	3			3		

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: BOD5		Thousands of Metric Tons Per Year						
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
37	Transportation Equipment	16				16		
4952	Sanitary Systems-Sewers	3632				3632		
TOTAL		10,030	n.a. [b]			11,801	11,637	1

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[a] Figure obtained from data given in ECW[66].

[b] n.a. = Not applicable as no overall total given.

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Suspended Solids		Thousands of Metric Tons Per Year						
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
201	Meat Products	538	180	970	12,18,91	970	680	31
202	and Dairy Prod.			680	12,18,91			
203	Processed Fruits and Vegetables	212	125	427	96	169		
204	Grain Mill Products		72	32	66	32		
208	Beverages		11			11		
20	Miscellaneous Food Products	6(P)[b]				6		
22	Textile Mill Products	208	177	215	93	262		
26	Paper and Allied Products	1491[a]	1444			1444		
281	Industrial Inorganic Chemicals	2019[a]	2019			2019		
282	Plastic Materials and Synthetics	150[a]	150			150		
283	Drugs	21[a]	21			21		

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Suspended Solids		Thousands of Metric Tons Per Year						
				. . . . Other. . . .				
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Final Estimate Controlled	% Control
2873	Nitrogenous Fertilizers	12				12		
2874	Phosphatic Fertilizers	21				21		
2879	Agricultural Chemicals nec	3				3		
28	Miscellaneous Chemicals	83[a]	86			86		
291	Petroleum Refining	74	108	82	90	92		
31	Leather and Leather Products	240				240		
331	Blast Furnace and Basic Steel Production	848[a]	848			848		
332	Iron and Steel Foundries	21[a]	21			21		
333	Primary Non-Ferrous Metals	116[a]	116			116		
335	Non-Ferrous Drawing, Rolling and Extruding	22[a]	22			22		

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Suspended Solids		Thousands of Metric Tons Per Year						
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
37	Transportation Equipment	18				18		
4952	Sanitary Systems-Sewers	4378				4378		
TOTALS		10,481	n.a.[c]			10,941	10,651	2

[a] Figure was obtained from data given in ECW[66].

[b] "P" indicates partial data.

[c] n.a. = Not applicable as no overall figure given.

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Nitrogen Compounds			Thousands of Metric Tons Per Year					
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
01	Agriculture-Crops	3742				3742		
02	Agriculture-Livestock	454				454		
201, 202	Meat Products and Dairy Products			145	12,15,16, 18,91,98	145		
2873	Nitrogenous Fertilizers (Manufacture)	2				2		
291	Petroleum Refining	32				32		
3312	Blast Furnaces (Coking)			91	16	91		
4952	Sanitary Systems Sewers	1089				1089	762	30
TOTALS		5,319				5,555	5,228	6

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Phosphorus Compounds				Thousands of Metric Tons Per Year				
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
01	Agriculture-Crops			73	94	73		
201, 202	Meat Products and Dairy Prod.			22	12,15,16 18,19	22		
281	Industrial Inorganic Chemicals	5				5		
2874	Phosphatic Fertilizers	19				19		
291	Petroleum Refining	3				3		
4952	Sanitary Systems-Sewers	245				245	171	30
TOTALS		272				367	293	21

TABLE B-1 (Cont.)

RECONCILIATION: NATIONAL SOURCES OF WATER POLLUTION

Pollutant: Sulfur Compounds		Thousands of Metric Tons Per Year						
				. . . . Other			Final Estimate	
SIC	Name	RSI[11]	ECW[66]	Estimate	Reference	Uncontrolled	Controlled	% Control
11,12	Anthracite Mining Bituminous Coal and Liguile Mining	998				998		
201, 202	Meat Products and Dairy Products			7	12,15,91	7		
291	Petroleum Refining	18				18		
4952	Sanitary Systems-Sewers	435				435		
TOTALS		1,451				1,458	1,458	0

TABLE B-2
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: BOD_5

SIC	Derivation of Final Estimate
02	Over 450 x 10^6 kg N as farm animal waste goes to water supplies (16,17); the weighted N/BOD ratio in animal manures is roughly 0.3 (17). Some of the wastes in land runoff from representative animal growing operations are given below, in kg/day/animal (95):

	BOD_5	N	N/BOD
Swine (direct discharge)	.080	.0146	.18
Dairy	.086	.0155	.18
Beef	.0136	.0036	.27
Poultry	.00023	.000009	.06

From known agricultural data (17) it can be calculated that the amounts of wastes produced by cattle far exceed the amounts produced by swine and poultry. The figures are 4.5 x 10^6 tons for cattle vs. 0.20 x 10^6 tons for swine and 0.18 x 10^6 for poultry per day. Hence, the weighted N/BOD ratio average is approximately $\frac{.18 + .27}{2} = .225$, which is not much different from the N/BOD ratio in manures.

Thus, 450×10^6 kg $N \div 0.225 = 2{,}000 \times 10^6$ kg BOD_5

201, 202 For sector 201, uncontrolled, RSI calculated 601 x 10^6 kg. The projections given for 1971[18] are 543 (meat) + 69 (poultry) = 612 x 10^6 kgs, uncontrolled, and 407 + 40 = 447 x 10^6 kg, actual production, yielding[18] 27 percent control. The extrapolation from ECW employee - BOD_5 data[66] gives a lower value for actual production, 109 x 10^6 kg. For sector 202, the most reliable estimate is 1814 x 10^6 lbs BOD_5, actual and mostly uncontrolled production.[12] This estimate was based on field investigations and is therefore likely to be more valid than estimates based on a survey of respondents as in ECW.

The final controlled estimate is composed of 447 x 10^6 for SIC 201[18] plus 1,814 x 10^6 for SIC 202[12], yielding respective uncontrolled figures of 612 x 10^6 plus 1814 x 10^6.

203 The estimate of RSI[11] is based on updating the inputs in Table 1 of reference 96 to 1971 amounts. The 376 x 10^6 kg figure is an estimate by the Federal Water Pollution Control Administration(96,p112) The final estimate is an average of the three estimates given.

204 By extrapolating 6.76 kg BOD_5/production employee/day in wet corn milling (SIC 2046) to all 79 x 10^3 production employees in SIC 204, 109 x 10^6 kg BOD are obtained. By extrapolating 11,340 kg BOD_5/5.68 million liters reported by

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: BOD_5 (Cont.)

SIC — **Derivation of Final Estimate**

only one plant in SIC 2046, to the total 67,600 million liters per year in SIC 2046, 135 x 10^6 kg BOD_5 are obtained. The former output is probably somewhat inflated, and yet it is lower than that derived from the wastewater data from one plant; hence, it is chosen as final.

208 The 680 x 10^6 figure relates to soft drinks only, in 1952-1954.[19] The ECW[66] data is presumably more comprehensive and more up-to-date.

20 The RSI figure is extrapolated from data from one California fish-processing plant. The ECW 11 x 10^6 figure also refers to fish processing, but on a nationwide sample. 36 x 10^6 are the kgs BOD_5 produced by the sugar beet industry.[13] The final estimate is the sum of these last two figures.

22 This sector presents special problems. The figures of actual BOD production given can be broken down as follows:

SIC	RSI[11]	ECW[66]	State of the Art of Textile Waste Treatment[93]
2211	-	64	--
2221	-	22	--
2231	41	11	60
226	358	114	376
Totals	399	211	436

The first and last totals are essentially the same; the last is a projection made in 1967, and the first is an estimate using similar pollution output coefficients applied to the actual activity in 1971. The figure from data in ECW might reflect either a very biased response for sector 226, or a change in pollution coefficients during 1967-1971. Since a clear selection criterion for the final estimate does not exist, the arithmetic average of the RSI (corrected for SIC 2211-2212) and ECW figures is considered final:

$$((399 + 64 + 22) + 211) \div 2 = 348$$

26 The RSI estimate is based on 2767 x 10^6 kg BOD from untreated effluent in SIC 261, plus 816 x 10^6 kg actual BOD production as estimated from ECW data for SIC 262 and 263. The actual contributions to BOD_5 according to the production employee extrapolations from ECW data are (in millions of kg/year):

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: BOD_5 (Cont.)

SIC	Derivation of Final Estimate
	SIC 261, 238; SIC 262, 626; SIC 263, 157; SIC 264, 712; and SIC 266, 6. The total adds up to 1,739 × 10^6 actual BOD_5 production. In 1967, a gross BOD_5 of 1.28 × 10^9 kg was predicted for 1971.[97] The final estimate of actual BOD_5 production is the average of the two totals : 1,509 × 10^6.
281-3	The RSI estimates are based on ECW production employee data. The figures in the ECW column were obtained by using the length-of-work-year data in ECW.
291	The RSI estimate updated the estimate in reference 90, and it is probably the most accurate estimate; it was therefore chosen as the final estimate.

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: Suspended Solids

SIC	Derivation of Final Estimate
201, 202	The SS/BOD ratio for uncontrolled slaughterhouses and packinghouses (SIC 201) is 2/3.(91,ch.16,p.13) According to Harper and Blaisdell,[12] SS/BOD = 0.31 (SIC 202). The RSI estimate, 2/3 x 601 x 10^6 kg BOD_5 (SIC 201) plus 0.31 x 441 x 10^6 kg BOD_5 (SIC 202) equals 538 x 10^6 kg BOD_5, uncontrolled. The figure derived from ECW is composed of an actual production (some controls are practiced) of 29 x 10^6 kg SS in SIC 201, and an actual production of 151 x 10^6 kg SS from SIC 2026 (fluid milk production only). The observations in Harper and Blaisdell [12] indicate that actual BOD_5 production in SIC 202 is 1.8 x 10^9 kg; hence, the SS production is 0.31 x 1.81 x 10^9 = 560 x 10^6. Since "over 90 percent" of dairy food plant wastes are treated by biological oxidation in municipal systems,[12] the 560 x 10^6 figure can be considered "uncontrolled" as well as "actual". The final estimate for SIC 201-202 is: uncontrolled, 2/3 x(612 x 10^6) + 560 x 10^6 = 970 x 10^6; controlled, 119 x 10^6 + 560 x 10^6 = 680 x 10^6. The 119 x 10^6 figure is the actual SS production (SIC 201) from ECW data, 29 x 10^6 kg times $\frac{447}{109}$, the ratio of "true" to ECW BOD_5 figures for SIC 201.(See derivation of final estimate section for BOD_5 in SIC 201).
203	For lack of a better criterion, the average of RSI and ECW is considered final.
204	As previously discussed for BOD_5, extrapolation from employee data on SIC 2046 to all employees in SIC 204 is likely to be inflated. While an extrapolation from the wastewater of one plant is not accurate, it is still the only plausible estimate available, since it is the smaller of the two figures given.
22	The circumstances are now the same as those discussed in the derivation of the final estimate for BOD_5. The final estimate is then: $((208 + 22 + 116) + 178)/2 = 262$
291	The RSI estimate updated the estimate from the American Petroleum Institute (90) and was averaged with the estimate from ECW to obtain the final estimate.

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: Nitrogen Compounds

SIC	Derivation of Final Estimate
201, 202	As calculated previously (see sector 201 BOD_5 derivation of final estimate), BOD_5 production in SIC 201 is approximately 454 x 10^6 kg. Assuming half of this comes mainly from blood and tissues of similar composition, and that blood has approximately 100,000 ppm BOD, (not an unreasonable assumption since N is5-8.6% of SS + TDS and N is 16% of protein weight), (91, chap 16, pp.,11,13), then 2,268 x 10^6 kg of blood (or equivalent) tissue are washed out. According to Hawk et al,[15] blood has approximately (on a wt/volume basis) 3.35% N (of which 99% is protein N) and .0275% P (of which only 14% is inorganic P). The ratio of N to S in muscle and in globulin is 16:1.[15] Since the specific gravity of blood is 1.06,[15] the 2,268 x 10^6 kg of blood (or equivalent) will have: 81 x 10^6 kg N 5 x 10^6 kg S 0.63 x 10^6 kg P Another estimate of pollutant N can be obtained from other sources. From data given,[18] it can be calculated that: the average live weight of a hog is 110 kg, and of a head of cattle is 454 kg. In 1966 the ratio of cattle to hogs slaughtered was 2:1 (live weight basis). Since there were 29 x 10^9 kg of live weight slaughtered in 1971, there must have been approximately 43 million head of cattle and 84 million hogs slaughtered. The N pollution from slaughtering is 0.68 kg N/head of cattle and 0.34 kg N/hog;[16] therefore, cattle and hogs slaughtered account for 57.6 x 10^6 kg N. The BOD/N ratio in combined poultry plant wastes is 10:1,(91,16,p11)and these wastes account for 69.4 x 10^6 kg BOD_5 per year,[18] or 6.9 x 10^6 kg N. The total N pollution in sector 201 is therefore 57.6 plus 6.9, or 64 x 10^6 kg N. A recent, fairly exact estimate of the BOD:N ratio in meat packing plant wastes is 10/1,[98] the same as that for poultry plant wastes. The final estimates for SIC 201, on the basis of BOD/N = 10:1, are: 45 x 10^6 kg N 2.8 x 10^6 kg S 0.35 x 10^6 kg P Then, 45 x 10^6 kg (SIC 201) plus 99.8 x 10^6 kg (SIC 202) equals 145 x 10^6 kg N In milk wastes there are 55 ppm N and 12 ppm P for each 1000 ppm BOD.[12] The ratio of P to S in milk and milk products is 5/1.[12] As noted previously (BOD5 derivation, sector 202), 1.8 x 10^9 kg BOD are produced. Hence, this corresponds to :

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: Nitrogen Compounds (Cont.)

SIC	Derivation of Final Estimate
	100×10^6 kg N 21.8×10^6 kg P 4.54×10^6 kg S
3312	Coking generates $45 - 136 \times 10^6$ kg N per year.[16] Hence, 91×10^6 kg is the "average".
4952	A 30 percent control was assumed[16] and on this basis the controlled production was calculated.

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: Phosphorus Compounds

SIC	Derivation of Final Estimate
201, 202	As calculated previously in the derivation of final estimate for N, the P production in SIC 201 is .35 x 10^6 kg, and in SIC 202 is 21.8 x 10^6 kg. Thus, 21.8 + .35 = 22 x 10^6 kg per year.

TABLE B-2 (Cont.)
DERIVATIONS OF ESTIMATES IN TABLE B-1

Pollutant: Sulfur Compounds

SIC	Derivation of Final Estimate
201, 202	As calculated previously in the derivation of final estimate for N, the S production in SIC 201 is 2.8×10^6 kg, and in SIC 202 is 4.54×10^6 kg. The total is therefore 7×10^6 kg.

Final Estimates of Uncontrolled Discharges for Key Industries.

Suspended solids and BOD_5 estimates before treatment for the major polluting sectors, as used for the present study, are summarized in Table B-3 along with other miscellaneous pollutants used in the determination of solid wastes from water pollution control.

The estimates available from previously published sources from Table B-1 also appear for ease of comparison. In general, the data for water pollutants were much less accurate than those for air pollutants (see Appendix A). Where significant discrepancies existed between the current study final estimates and the preliminary data in Table B-1, the reasons are explained in the footnotes to Table B-3.

TABLE B-3

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

SIC	Description	Suspended Solids		BOD$_5$		Other		
		Final	Prelim.	Final	Prelim.	Pollutant	Final	Prelim.
02	Feedlots	10,080		n.d.	2,000	Total dry solids		
10,11,12,14	Mining					Acid mine drainage All mines	3,600	
						Acid mine drainage, active mines	1,440	
		8 x 10^5				Mine tailings	12,000	
							1,200	
201,202	Meat and dairy products	550[a]	970	700[a]	2,426	P,Cl,TDS	257	
203	Canned and preserved fruits & vegetables	390[b]	169	350	405			
26	Paper & allied products	860[c]	1,444	2,010	1,509			
28	Chemicals & allied products	510	2,312		538	SS + TDS	16,782	
13,291	Petroleum refining, extraction, & transportation	35	92	100				
324,325	Cement & clay	10		n.d.		TDS	108	

TABLE B-3 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

		Suspended Solids		BOD_5		Other		
SIC	Description	Final	Prelim.	Final	Prelim.	Pollutant	Final	Prelim.
331	Blast furnaces & basic steel	11,300[d]	848	n.d.		Pickle liquor		
						$FeSO_4$	460	
						H_2SO_4	123	
333,334	Primary & secondary non-ferrous smelting & refining	7,250[d]	116	n.d.				
4952	Sewerage systems	4,610		3,970	3,632	Solids	4,614	
Other Sources:								
208	Beverages	10	11	440	445			
20	Misc. food products	40	6	60	47			
22	Textile mill products	260	262	350	348			
31	Leather	100	240	70	85			
335	Nonferrous rolling & drawing	20	22	3	3			
37	Transportation equipment	20	18	20	16			
	Total without mining	36,045	6,510	8,070	11,454			

TABLE B-3 (Cont.)

FINAL ESTIMATES OF NATIONAL DISCHARGES BEFORE TREATMENT OF WATER POLLUTANTS CAPABLE OF GENERATING SOLID WASTE - 1971

[a] Suspended solids and BOD_5 figures in Appendix D were estimated from the Cost of Clean Water. The current report data used the Cost of Clean Water and the recently released effluent guidelines reports. The current analysis was performed in much more detail than the preliminary estimate in Appendix D.

[b] The data in Appendix D were taken from a very general analysis. The final report estimate used was based mainly on the effluent guidelines for canned and frozen fruits and vegetables which is much more detailed.

[c] The data in Appendix D are taken from the Cost of Clean Water without any independent estimate of production. The current report estimate utilized mainly this same source but estimated paper production independently and also performed a more detailed analysis of the Cost of Clean Water.

[d] The Appendix D estimate was very incomplete, and taken from The Economics of Clean Water. The final current report estimate used the Cost of Clean Water and an estimate of water pollution created by air pollution controls. These residues are thus not completely separate from air pollution residues. This fact was considered in the total estimate of solid wastes.

APPENDIX C

TELEPHONE SURVEY OF INDUSTRIAL POLLUTION TREATMENT AND WASTE DISPOSAL PRACTICES

Table C-1 summarizes the results of a telephone survey conducted of personnel responsible for pollution control activities in key sectors responsible for solid wastes generated by pollution control activities. The respondents were assured that their responses would remain anonymous.

This survey was necessary to fill several very important gaps in the information required to make the projections required in this study. The prevalent methods of controlling air and water pollution and the waste disposal practices in the industries surveyed were identified. In some cases quantifications of the solid wastes generated by air and water pollution controls were given by the respondents. In general cooperation with the survey was very good with only two respondents refusing to provide answers to the survey questions. The survey was especially valuable in identifying the methods used to dispose of the residues and the potentials for their reuse or sale.

TABLE C-1

INDUSTRY PHONE SURVEY SUMMARY

	Industry		
SIC	Description	Pollution Control Equipment	Residue Disposal
02	Cattle feedlot	Manure removed by professional hauling firm	Used as soil conditioner
		Same removal	Used as protein supplement
19	Clay and silica sand mine	Baghouses	Residue is sold in solid form at a loss
		Water pollution control –closed resevoir system – no effluent	Sludge recycled to product
		Future thickening and clarification plants	Some landfill, some to recycle
10	Iron ore, pellets, fines	Baghouses	Residue included in fine product piles
		Closed circuit reservoir	Residues to landfill
		Beneficiation plant, thickener underflow	To tailings Total tailings=2.3–2.7 x 10^6 kkg/year from thickeners = 50–100 acre feet/month
	Copper mine	Tailing ponds	Sediment impounded on site
	Lead and zinc mining and concentrates	Tailing ponds	4,545 kkg tailings(dry) per 5,455 kkg ore – impounded on site
	Copper mine and smelter	Smelter baghouses	Recycle as new ore
		H_2SO_4 recovery plant for SO_2 control (efficiency=60%)	Sold
		Tailing pond, polishing basin for 20–30x 10^3 tons ore/clay at .6–.8% copper	Impounded on site = 1, 827 x 10^3 kkg/day
14	Lime rock mine	Baghouses and scrubbers in mill	Mostly recycled in product
		Lime kiln scrubber	Slag or hydrated lime to on site dump in desert
		Plant water pollution control	Underfeed is included in in product
		Domestic wastes	On site septic tanks
201	Meat slaughtering	Screening and retention tank	Vacuum truck to rendering plant or to landfill
		Screenings and offal	To rendering plant 38,864 kg /day at 90 kg/head wet weight

TABLE C-1 (Cont.)

INDUSTRY PHONE SURVEY SUMMARY

SIC	Industry Description	Pollution Control Equipment	Residue Disposal
201	Meat slaughtering (Cont.)		
		Stomach contents and manure from holding pens	To fertilizer company 4,545 kg stomach contents per day plus 1,364 kg/week manure
		Clarifier	Grease to rendering = 1,023 kg /day Sediment to landfill ≃ 1,023 kg /day
	Pork slaughtering	Water pollution control	Cook all wastes for fertilizer production
	Fish products and lima beans	Flotation systems	Used as soil conditioner
	Rendering plant	Effluent water	To sewers
		Tallow and meat wastes	Tallow and meat and bone meal
		Sewer grease	50% to landfill, 50% grease to tallow
		Blood meal, offal, screening	Tallow or meat and bone meal
203	Canned vegetables, various plants	Screenings	Landfill, cattle feed, spray irrigation or drying for fur-bearing animal feed Some discharge to sewers
		Dry peeling is in its infancy but will increase, especially for potatoes and peaches	Solid wastes to above disposal alternatives
26	Paper products no pulping	Paper machine drum retention process for water removal	Some solids. They are recycled in system
	Unbleached kraft pulp 1,100 kkg/day	Electrostatic precip. for air pollution	Recycled to pulp
		Lagoon	13,641 kg/day $CaCO_3$ from lime kiln-waste requires periodic removal
	Unbleached kraft pulp and liner board	Lime kiln scrubber	$CaCO_3$ to clarifier for recycling

TABLE C-1 (Cont.)

INDUSTRY PHONE SURVEY SUMMARY

Industry			
SIC	Description	Pollution Control Equipment	Residue Disposal
26 (Cont.)	Unbleached kraft pulp and liner board (Cont.)	Primary water pollution control to clarifier	All recycled
		Reject stream from clarifier	To settling pond, effluent to ocean. Solids eventually will fill the pond
		Future secondary treatment	Will increase recycled material
		Make pulp from wood chips that used to be burned in wigwam burners	
	Kraft and sulfite bleached pulp	Electrostatic precipitator on recovery boiler	All recycled in system
		Lime kiln scrubber	All recycled in system
		Screening and activated sludge	Landfill (50%),burn, or aerated lagoon
		Color control	pH adjustment only
		Waste $CaCO_3$	All recycled in system
28	Ammonia, nitric acid, ammonium nitrate, natural gas	Baghouses on diatomaceous earth anti-caking agent	Recycled to product as additive
		Skimming and sedimentation	Grease-1 truck/6 months to landfill; sediment - 1 truck/3 years to landfill
	DDT plant	Scrubbers and baghouses	Recycle and some to Class I dump, pyrolysis possible in future
		Salt removed from recycled water	Calif. Class I dump
	Plastics-polystyrene, etc.	Electrostatic precip. to catch styrene dymers	Landfill but less than 11.4 kg/day
		Filters in future	Filter media to landfills
		Activated carbon(pending)	Regenerate with boiler steam
		Water pollution	Effluent to sewer, untreated sludge from sewer to sea or land
291	Petroleum refining 200,000 bbl/day crude throughout	H_2S in recovery	Sulfur sold as by-product
		Catalyst fines (aluminum silicate)	Landfill
		Gravity separation plus air flotation	Landfill 400 bbl/day

TABLE C-1 (Cont.)

INDUSTRY PHONE SURVEY SUMMARY

SIC	Industry Description	Pollution Control Equipment	Residue Disposal
291	200,000 bbl/day crude throughout (Cont.)	Beach oil spill cleanup - straw is on way out. A newer method is road grader removal of oil and sand on beach	Land disposal
		Ocean oil spill skimming	Reprocess all or, if contaminated, send to landfill
32,14	Mining and clay pipe prod.	Baghouses	Dust to clay preparation as fines
		Wash rack and sump sediment	Disposal in mine and in on-site heaps
		Air and water pollution solid wastes	0.2 m^3/week off-site 0.2 disposal
32	Clay products (10^3 kkg/day production)	Settling ponds	0.9 kkg/day to dump
	Brick products	Baghouses	Add fines back to batch
	Dry process portland cement	Cyclones (first 80% removed)	Recycled in product
		Precipitators and baghouses (last 20%)	On site tailing ponds
		Additional controls in future if required	All waste as fines are not suitable for recycling
331	Steel mill	Baghouses on basic oxygen furnaces	Recycle to sinter
		Baghouses on open hearths	Sell to cement plants
		Blast furnace scrubber	Recycle to sinter
		Water pollution control sludge	To slag heap and then to cement plant
		Further air and water controls if required	Will generate wastes as these final fines are not suitable for recycling
32	Steel mill from scrap and pig iron (36-45,000 kkg /month of steel)	Baghouse on electric arc furnace	Fines to fertilizer plant for trace minerals (18.2 kkg/week)
		Water pollution control	Class I landfill 3.6-4.5 kkg per week mainly iron oxides & some sulfates

TABLE C-1 (Cont.)
INDUSTRY PHONE SURVEY SUMMARY

	Industry		
SIC	Description	Pollution Control Equipment	Residue Disposal
333	Aluminum, lead smelting and refining	Baghouses and scrubbers	Recycle to same plant or other plants
		H_2SO_4 recovery (50-60% eff.)	Sell as by-product. Market is very bad and will probably get worse
		May need limestone scrubbing in future	Land disposal, high epsom salts content
		Tailing ponds	Impounded on site
	Zinc smelter	Lime flocculation sedimentation, and pH adjustment	Land disposal
334	Secondary copper smelter and brass products	Baghouse dust	Sell to reclaimer who produces zinc sulfate
		Primary and secondary water pollution control systems	Sludge to ocean disposal or landfill
	Secondary lead plant	Baghouses	Recycle back to furnace
		Water pollution control-closed water jacket	Almost no wastes-some salt removal
	Secondary zinc refinery	Baghouse dust	85 percent recycle, 15 percent to landfill
		Settling ponds	Small amounts to landfills
		Future controls	Higher percent waste as grade of residues will be lower

APPENDIX D

AIR POLLUTION CONTROLS AND RESIDUES CREATED, AS IDENTIFIED BY THE LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT

Table D-1 presents a summary of the air pollution control practices in Los Angeles County as identified by personnel of the Los Angeles County Air Pollution Control District. The information was obtained during the study, Intermedia Aspects of Air and Water Pollution Control by Ralph Stone and Company, Inc. from Eric E. Lemke, Engineering Director of the APCE.[11] This information, in addition to the data from the phone survey presented in Appendix C, was used in making the estimates of current and future treatment and disposal practices in the key industries responsible for the generation of solid wastes from air and water pollution control.

TABLE D-1[323]

AIR POLLUTION CONTROLS AND RESIDUES, LOS ANGELES COUNTY, CALIFORNIA, AS ESTIMATED BY THE AIR POLLUTION CONTROL DISTRICT

SIC Code	Description	Controls	Residues
01	Agricultural burning	Banned completely in basin Burn days only in high desert area	Solid waste to landfill
	Orchard heaters	Banned - now use pans	None
20	Food industry	Afterburners for hydrocarbons	Gaseous combustion products
204	Feed mills and grain elevators	Cyclones and baghouses	Solid residue Animal feed residues - Recycled back into product Food grain residues mostly used in animal feed.
2077	Rendering industry	Scrubbers (particulates and condensable hydrocarbons)	Residues to water - to county sanitation districts or city sewer systems.
2819	Sulfuric acid plants	SO_x control by dimethylaniline, amine or similar process	Regenerative process burns H_2S to SO_2 then adsorbs SO_2 on amine to yield H_2SO_4, the amine is regenerated. H_2SO_4 is sold or used.
2834	Pharmaceuticals	Baghouses	Solid waste reuse in product or if not re-usable deep well disposal because of hazards in landfill disposal.
2911	Petroleum refining coke handling	Hydrocarbons - afterburners scrubbers	Gaseous combustion products in water - mostly back to coke bins.
2951	Hot asphalt	Scrubbers - still 50 percent in use but being phased out; can barely meet current standards	Water residue to ponds on premises, overflow to sewers. Every few years dredge ponds - dispose to landfills.

TABLE D-1[323] (Cont.)

SIC Code	Description	Controls	Residues
2951 (cont.)		Baghouses more efficient than scrubbers; 50 percent of controls are now baghouses.	Reintroduce fines into asphalt - aids quality of asphalt.
3272	Concrete batching	Process control - 3 percent water addition to process keeps dust down	Water kept in ready-mix.
	Gravel pits	Water sprays	Drain to gravel pit - water recharges ground water.
33-34	Metallurgical processes	Fine emissions - baghouses, scrubbers (less than 10 percent)	Solid waste water
	Zinc wastes	Baghouses	Recycle zinc as valve is high - sold for use in paint, etc. - Zn O_2
5541	Gas stations	New requirements will control vapor loss - will use return systems for auto tank and underground tank filling systems	None
72	Dry cleaning	Hydrocarbons, activated carbon - regenerate with steam for new stricter standards,currently no controls on this many cleaners,lose 50 gal make-up/month	Steam will carry some loss to water Air, water
20-39	Industrial fuel combustion	Afterburners	Gaseous combustion products
		Process methods: alternating fuel-rich,fuel-lean combustion in series with mixing of exhaust air (stoichiometric control) this is only feasible for big fuel users	Gaseous combustion products

TABLE D-1[323] (Cont.)

SIC Code	Description	Controls	Residues
20-34	Degreasing operations	Process control: Temperature of operation.	Gaseous combustion products, some increased NO_x in eliminating CO.